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McClellan Air Force Base

Davis Global Communications Site

Remedial Investigation/ Feasibility Study Report

Volume I of III

Delivery Order 5055

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We have endeavored to include all comments and concerns in this revision of the document. If you have any further questions, please call me at (916) 643-0830, ext 381

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Remedial Project Manager, Davis Site
Environmental Restoration Division
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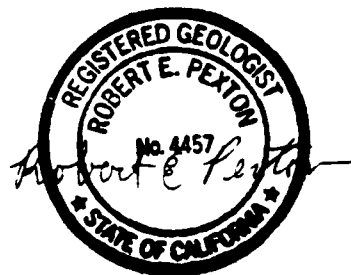
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Final
Davis Site
Remedial Investigation/Feasibility Study Report
Volume I of III

Prepared for
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Line Item 0021



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Executive Summary

A Remedial Investigation/Feasibility Study (RI/FS) was performed at the McClellan Air Force Base (McClellan AFB) Davis Global Communications Site (Davis Site) from June 1992 through August 1993. This report presents the results of the RI/FS as well as a compilation of the remedial investigations (RIs) that have been performed at the Davis Site since 1985. The purpose of the RI/FS was to provide an implementable strategy for site remediation that complies with environmental restoration goals set forth in the Federal Facilities Site Remediation Agreement (FFSRA). The FFSRA was signed in 1992 by McClellan AFB and the State of California's Department of Toxic Substances Control and Regional Water Quality Control Board.

Site Background

The Davis Site is an annex of McClellan AFB located approximately 4 miles south of the City of Davis. The site covers 316 acres in Yolo County and is surrounded by farmland. The site was built in the early 1950s as a transmitter facility of the Department of Defense for western hemisphere operations. It is currently staffed 24 hours a day with approximately 12 members of the 2049th Communications Squadron.

In 1985, three underground diesel-fuel tanks and associated piping were discovered to be leaking diesel fuel. The three storage tanks were drained and removed in 1988. During the underground tank investigation, groundwater samples from beneath the site were found to contain measurable levels of volatile organic compounds (VOCs). Both VOC and hydrocarbon contamination from diesel fuel remain in both the vadose zone and in the groundwater beneath the site. It is speculated that historic disposal practices of cleaning solvents is the source of VOC contamination at the site. This report focuses on the VOC contamination beneath the site. Currently, a bioventing treatability study addressing the hydrocarbon contamination is being performed separate from the RI/FS. Pending the results of that study, this report does not address hydrocarbon contamination as a portion of the remedial action.

Remedial Investigation/Feasibility Study Approach

The approach for the RI/FS relied on using data from previous investigations to identify areas of uncertainty. Field investigations were then performed to reduce or eliminate the uncertainty. Objectives for the RI/FS were divided into vadose zone and groundwater actions. The vadose zone objectives included determining the extent of soil gas contamination, identifying areas of VOC contamination, identifying areas

where soil vapor monitoring wells should be installed, and providing contaminant data that could be used in human health or ecological risk assessment activities.

The vadose zone objectives were met by performing an extensive shallow soil gas survey covering the eastern third of the fenced compound and north and east of the fenced compound area. The shallow soil gas survey identified areas of VOC contamination within the vadose zone. In areas of high VOC contamination, soil vapor monitoring wells were installed and sampled for VOC contamination. The shallow soil gas survey and soil vapor monitoring well sampling provided contaminant concentration data that were used to develop VOC mass estimates for the vadose zone.

The groundwater objectives included determining the extent of contamination and seasonal variations in water quality; describing the site hydrogeology; characterizing seasonal variation in flow direction, vertical and horizontal hydraulic gradients; and determining the presence of both coarse- and fine-grained units to estimate their potential to act as aquifers or aquitards.

The groundwater objectives were fulfilled by performing field investigations and then subjecting the findings to hydrogeologic and engineering evaluations to produce a hydrogeologic model of the site. The investigations included installing a total of 13 new wells, conducting several aquifer tests on existing wells, and measuring water levels in new and existing wells. As a result of the hydrogeologic evaluation, the site has been divided into five hydrogeologic zones—A, B, C, D, and E.

These zones extend to a depth of 245 feet below the site and include both permeable aquifer materials (sand and gravel) and low permeability aquitard materials (silt and clay). The low permeability materials, which generally exist across the site between aquifers, are termed aquitards and have been named the A-B, B-C, C-D, and D-E aquitards. The A zone (vadose zone) ranges from ground surface to 65 feet below ground surface (bgs) and contains the A-B aquitard; the B zone ranges from 65 to 95 feet bgs and contains the B aquifer; the C zone ranges from 95 to 145 feet bgs and contains the B-C aquitard and the C aquifer; the D zone ranges from 145 to 195 feet bgs and contains the C-D aquitard and the D aquifer; and the E zone ranges from 195 to 245 feet bgs and contains the D-E aquitard and the E aquifer.

Sampling of groundwater from monitoring wells at the Davis Site is performed by Radian Corporation on a quarterly basis. This RI/FS Report includes data collected through July 1993. These data are used as the basis for the findings and recommendations presented in this report, including development of mass estimates, target areas and volumes, and groundwater modeling.

Groundwater levels in the area of the Davis Site typically fluctuate 30 feet or more per year as a result of agricultural pumping near the site. The magnitude and direction of horizontal hydraulic gradients vary considerably between the upper (B and C aquifers) and the lower aquifers. Vertical hydraulic gradients are typically steeply downward

Vadose Zone	A-B Aquitard	0
B Zone	B Aquifer	65
C Zone	B-C Aquitard C Aquifer	95
D Zone	D-C Aquitard D Aquifer	145
E Zone	D-E Aquitard E Aquifer	195
		245

Depth in feet

Aquifer/aquitard boundaries are not clearly defined because of stratigraphic discontinuities across the site.

during the summertime (from the B and C aquifers to the D and E aquifers) and slightly upward during the wintertime (from the D and E aquifers to the B and C aquifers).

Distribution of Contamination

Historical groundwater quality and soil gas data were evaluated for the occurrence and distribution of VOC and semi-VOC contamination. A preliminary risk assessment was performed to evaluate the risk posed by the distribution of contamination within the vadose zone and groundwater. From this evaluation, a list of contaminants of concern (COCs) was generated based on whether the contaminant posed greater than 1 percent of the total risk for the groundwater and vadose zone. Several semi-VOCs associated with diesel fuel were identified as COCs in the risk evaluation. Because these compounds are associated with the hydrocarbon contamination, they were not considered as COCs for the RI/FS. A subset of the total COCs for the site (SCOCs) was generated for the groundwater and vadose zone. The SCOCs for the vadose zone include tetrachloroethene (PCE), trichloroethene (TCE), 1,1-dichloroethene (1,1-DCE), benzene, vinyl chloride, toluene, and xylene. Groundwater SCOCs include PCE, TCE, 1,1-DCE, benzene, vinyl chloride, 1,1-dichloroethane (1,1-DCA), and trans and cis isomers of 1,2-DCE.

An estimate of the total mass of contamination present beneath the site was calculated. The estimate is shown in Figure ES-1. Approximately 324 kilograms (kg) (715 lb) of contamination is estimated to be distributed throughout the subsurface at the Davis Site. The estimated mass of contamination per depth zone is shown in Figure ES-1. Over 85 percent of the contamination resides above the C-D aquitard beneath the site. The most prevalent compounds in terms of contaminant mass are PCE, TCE, and 1,1-DCE.

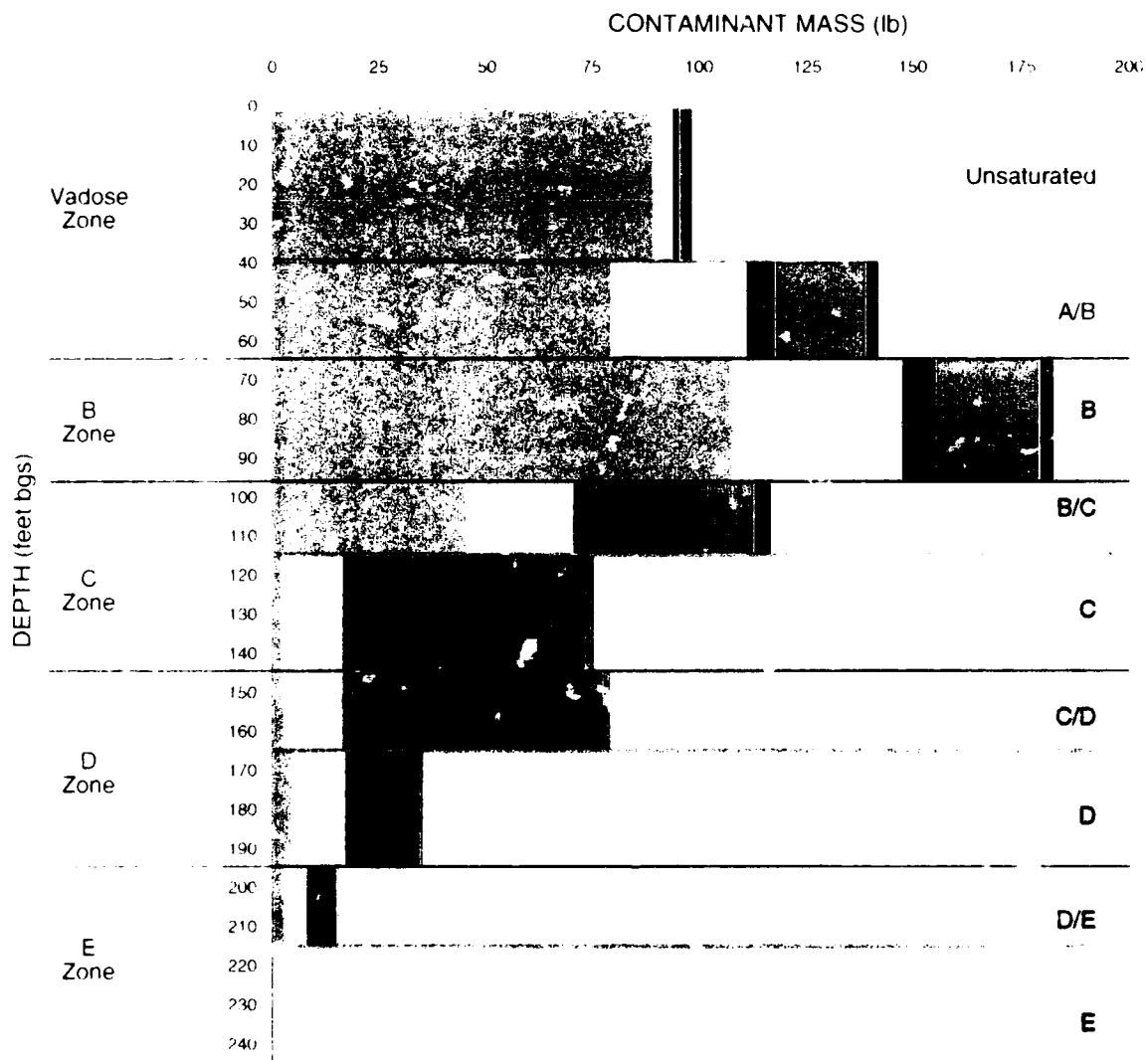
Contaminant Movement

The RI findings are presented in Chapters 1 through 5 of this report. Field investigation activities are profiled in Chapter 2; site hydrogeology is described in Chapter 3; and Chapter 4 presents interpretation of the analytical data regarding contaminant movement in terms of the hydrogeologic model. Of particular interest is Figure 4-7, located in Chapter 4. This figure depicts the conceptual model for the site, showing potential and probable contaminant pathways through the subsurface.

Through vadose zone modeling, it was determined that the occurrence of VOCs in the vadose zone could be a continuing source of groundwater contamination for hundreds of years if left unchecked. The contamination is located primarily north and east of the fenced compound area.

It was determined that VOC groundwater contamination has been spreading both outward and downward beneath the site. The level of dissolved VOC contamination within the B aquifer has decreased during the last 5

SCOCs	
Vadose Zone	Groundwater
PCE	PCE
TCE	TCE
1,1-DCE	1,1-DCE
Benzene	Benzene
Vinyl Chloride	Vinyl Chloride
Toluene	1,1-DCA
Xylene	1,2-DCE



LEGEND

- PCE
- TCE
- 1,1-DCE
- 1,1-DCA
- 1,2-DCE (cis & trans)
- Vinyl Chloride
- Benzene
- Xylene
- Toluene

FIGURE ES-1 SUMMARY OF CONTAMINANTS

DAVIS GLOBAL COMMUNICATIONS SITE
McCLELLAN AIR FORCE BASE
YOLO COUNTY, CALIFORNIA

years, while the level of contamination within the C and D aquifers has increased.

Risk Assessment

Chapter 5 presents a summary of the preliminary risk assessment, which was completed as a separate document. The preliminary risk assessment addresses both human health risks and ecological effects associated with contamination detected at the Davis Site. The preliminary risk assessment was based on a reasonable maximum exposure (RME) scenario and was developed in accordance with applicable federal, state, and Installation Restoration Program guidance.

Results of the risk assessment indicate that:

- Conditions do not exist that pose imminent or substantial danger to human health or the environment.
- Some action may be required to reduce future risks to human health associated with contaminants detected in groundwater.
- Further action is not indicated to reduce human health risks associated with direct contact exposures (soil ingestion and dermal contact), to petroleum hydrocarbon contaminants in soil or inhalation exposures from emissions of VOCs from soil gas to the air.
- Ecological resources potentially at risk are limited. Certain remediation activities could result in small losses of foraging habitat for Swainson's hawk.

Remedial Action Objectives

Remedial action objectives developed for the Davis Site include the following:

- Reduce or eliminate levels of subsurface contamination that pose a potential threat to human health or the environment.
- Prevent the spread of groundwater contamination beneath the site, especially to regional aquifers.
- Provide implementable strategies for remedial actions as quickly as possible and still maintain compliance with the FFSRA schedule.

Screening of Potential Remedial Actions

The FS is presented in Chapter 6. Remedial action alternatives for the vadose zone and groundwater are developed in Chapter 6. No-action cleanup options are presented for both the vadose zone and groundwater

to provide a baseline against which the actions can be compared. The alternative selection process of the FS is diagramed on Figure ES-2. Four alternatives were evaluated for the FS:

- Alternative 1—No cleanup for either the vadose zone or the groundwater (the No-Action Alternative)
- Alternative 2—Soil vapor extraction (SVE) for the vadose zone and no action for the groundwater
- Alternative 3—Groundwater extraction with no action for the vadose zone
- Alternative 4—Both SVE and groundwater extraction

Each cleanup option consists of a capture, treatment, and end-use component. The four alternatives are then compared against each other and the nine Superfund evaluation criteria. Innovative options for cleanup are discussed which could enhance vadose zone and groundwater remediation. The alternatives are evaluated using two separate groundwater target volumes. Target Volume 1 consists of contamination present above the C-D aquitard. Target Volume 2 consists of all known contamination from the land surface down to the bottom of the E aquifer.

The remedial action will be selected by McClellan AFB and must meet approval by the California Environmental Protection Agency. This report and its recommendations have been structured to be compatible with existing planned intermediate remedial actions as well as remedial actions that are currently being implemented.

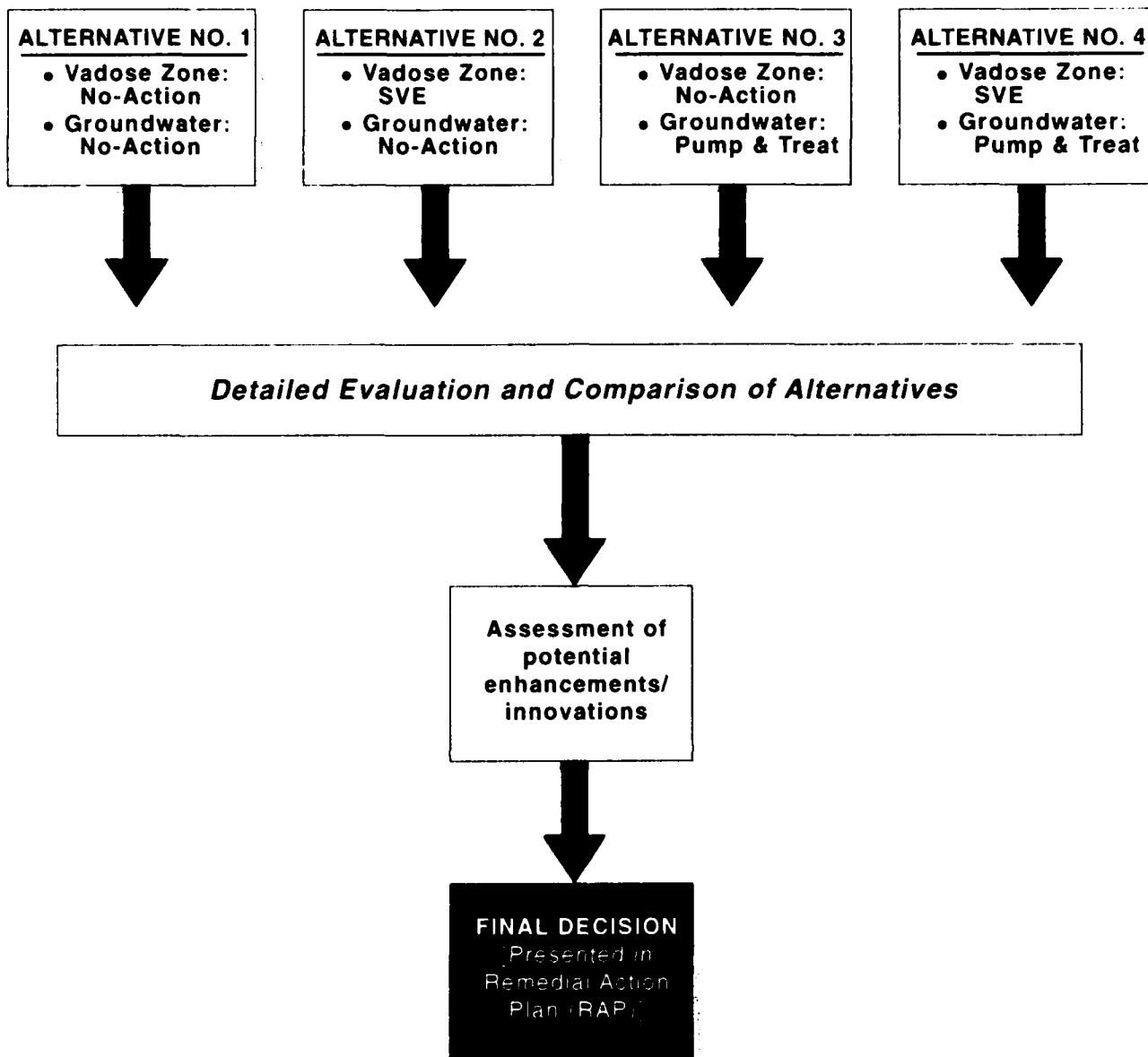
Site characterization uncertainties are addressed in the FS in terms of contingencies for the remedial action options. For example, if the estimated aquifer transmissivities are higher than actual transmissivities, additional wells would be required for groundwater capture. This translates into additional cost for well construction, piping, and operation and maintenance. Uncertainties and associated contingencies are tabulated in Chapter 6.

Conclusions

A full list of conclusions generated during the site evaluation are presented in Chapter 7, along with recommendations for additional work. The list of COCs and potential remedial actions for each COC is tabulated in Chapter 7.

The following is a synopsis of the conclusions:

- If left unchecked, vadose zone contamination will continue to degrade groundwater quality for several hundred years.
- Steep downward vertical gradients and increased horizontal gradients that exist beneath the site during the late spring



**FIGURE ES-2
ALTERNATIVE SELECTION
DECISION PROCESS**
DAVIS GLOBAL COMMUNICATIONS SITE
McCLELLAN AIR FORCE BASE
YOLO COUNTY, CALIFORNIA

and summer promote contaminant movement from shallow, more contaminated zones to deeper, less contaminated, more transmissive aquifers. This results in larger target volumes for groundwater remediation, especially in the C, D, and E zones, which translates into higher costs for the eventual remedial action.

- Implementation of soil vapor extraction within the vadose zone would reduce or remove the threat of contaminant loading to the groundwater.
- Groundwater extraction and treatment would inhibit offsite movement of groundwater contamination and serve to remediate subsurface contamination to levels accepted by the California Environmental Protection Agency.

Report Volumes II and III

Volume II of this report contains Appendixes A through P. These appendixes present more detailed information concerning various investigations and evaluations conducted as part of the Davis Site. Volume II includes a discussion of the soil gas investigation (Appendix A), air permeability testing (Appendix B), treated groundwater reuse soils investigation (Appendix C(a)), geotechnical exploration for the onsite reservoir (Appendix C(b)), and a summary of field activities (Appendix D).

Groundwater contour maps are presented in Appendix E, mass estimates for COCs are discussed in Appendixes F(a) and F(b), and an analysis of potential ARARs is presented in Appendix G. Appendix G will be updated following receipt of the ARARs solicitation. Vadose zone contamination impacts are discussed in Appendix H; and soil vapor extraction, groundwater extraction, and hydrocarbon remediation are discussed in Appendixes I, J, and K, respectively.

SVE gas and stripper offgas treatment are evaluated in Appendix L; groundwater treatment and end-use options are discussed in Appendixes M(a) and M(b). Natural biological groundwater attenuation is presented in Appendix N; dual-phase extraction is discussed in Appendix O; and Appendix P presents information concerning data validation.

Volume III contains lithologic and geophysical logs (Appendix Q), cone penetrometer data (Appendix R), well construction data (Appendix S), hydropunch data (Appendix T), and historical contaminant data (Appendix U).

A preliminary risk assessment for the Davis Site has also been prepared as a separate report and is being submitted concurrently with this RI/FS Report.

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Risk Assessment Report Bound Separately

Glossary of Terms

AB	Assembly Bill
adsorption	the accumulation of gases, liquids, or solutes on the surface of a solid or liquid
advection	a local change in the properties, such as temperature, of an air mass caused by the horizontal movement of the air mass. Contaminant release is advection-controlled when the rate of contaminant removal rises with increased vapor extraction system flow.
aerifer	a geologic unit through which air can flow to an extraction well; analogous with the term "aquifer," but for air rather than water
aeritard	a geologic unit that retards the flow of air; analogous with the term "aquitard," but for air rather than water
alternative	For the Davis Site, four alternatives have been developed: (1) no action for the vadose zone or groundwater; (2) soil vapor extraction of the vadose zone and no action for groundwater; (3) no action for the vadose zone and pump and treat the groundwater; and (4) soil vapor extraction for the vadose zone and pump and treat the groundwater.
anaerobic dehalogenation	the process of removing halogens from halogenated compounds by replacing them with hydrogens under anaerobic conditions
aquifer	an underground zone of earth, gravel, or porous stone that yields water; beneath the Davis Site, as many as seven different coarse-grained units have been defined as aquifers and given letter designations A through G, sequentially increasing with depth. This report discusses the B, C, D, and E aquifers.
aquitard	an underground low permeability zone that restricts or retards the passage of water from an overlying or lower-lying aquifer. This report references the A-B, B-C, C-D, and D-E aquitards.
ARARs	Applicable or Relevant and Appropriate Requirements
atm	atmosphere
BACT	best available control technology
BDAT	best demonstrated available treatment technology
bgs	below ground surface

biotransformation	the biological processes that lead to transformation of a compound; such as complete mineralization of a compound to carbon oxide and water, uptake and incorporation of the compound into the microorganism as cell material, conversion of the compound to metabolic end products, or reduction/oxidation of the compound to other compounds
bioventing	a technique where air is applied to the vadose zone to increase soil gas oxygen, and thereby increase aerobic biological activity, allowing micro-organisms to break down contaminants
BTEX	benzene, toluene, ethylbenzene, and xylenes
Ca	calcium
CAA	Clean Air Act
CAAQS	California Primary and Secondary Ambient Air Quality Standards
Cal/EPA	California Environmental Protection Agency; Cal/EPA is composed of the Department of Pesticide Regulation, the Department of Toxic Substances Control, the Office of Environmental Health, the Air Resources Board, Integrated Waste Management Board, State Water Resources Control Board, and nine Regional Water Quality Control Boards. In this RI/FS, Cal/EPA encompasses the Department of Toxic Substances Control and one of the nine Regional Water Quality Control Boards
CARB	California Air Resources Board
CatOx	catalytic oxidation
CCR	California Code of Regulations
CEC	cation exchange capacity
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (the Superfund law)
CH ₄	methane
cis-1,2-DCE	cis-1,2-dichloroethene
CLP	Contract Laboratory Program
CO	carbon monoxide
CO ₂	carbon dioxide
COCs	contaminants of concern

COD	chemical oxygen demand
COE	U.S. Army Corps of Engineers
cometabolic elements	the elements necessary for cometabolism to occur
cometabolism	the process whereby a "primary substrate" such as toluene, ethyl benzene, or others, induces production of non-specific enzymes that oxidize chlorinated aliphatics such as TCE. This process can "biotransform" contaminants in groundwater to a nonhazardous state.
component	For the Davis Site, capture, treatment, and end use are the components of vadose zone and groundwater cleanup options.
CORA	a computer program for cost estimating. Uses the site conditions and selected treatments to calculate capital and O&M costs for each treatment, along with site preparation costs.
CPT	cone penetrometer test
CVRWQCB	Central Valley Regional Water Quality Control Board
CWA	Clean Water Act
Davis Site	McClellan Air Force Base Davis Global Communications Site
1,1-DCE	1,1-dichloroethene
1,2-DCE	1,2-dichloroethene
desorption	the process of removing an absorbed or adsorbed substance
DHS	State of California Department of Health Services, known as DTSC, Department of Toxic Substances Control
diffusion	the spontaneous intermingling of two or more substances as a result of random thermal motion. Contaminant release is diffusion-controlled when the contaminants migrate into the vapor phase at a relatively slow rate that does not depend on the magnitude of soil vapor extraction system flow.
DNAPL	dense non-aqueous phase liquid
DREs	destruction and removal efficiencies
DTSC	State of California Department of Toxic Substances Control
dual-phase extraction system	a system designed to simultaneously remove soil gas and water from a single well screened at or above the water table
EBT	electron beam technology

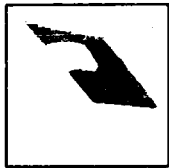
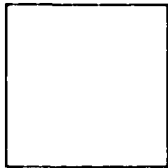
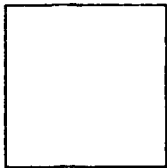
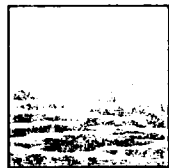
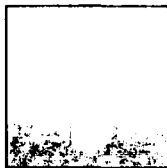
EC	electrical conductivity
EDB	ethylene dibromide
EPA	U.S. Environmental Protection Agency
ESI	Engineering-Science, Inc.
FFSRA	Federal Facilities Site Remediation Agreement
FID	flame ionization detector
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FRP	fiberglass-reinforced plastic
FS	feasibility study
GAC	granular activated carbon
GC	gas chromatograph
GC/MS	gas chromatograph/mass spectrometer
GC/TCD/FID	gas chromatograph/thermal conductivity detector/flame ionization detector
GSAP	Groundwater Sampling and Analysis Program
HA	health advisory
halogen	any of the five elements fluorine, chlorine, bromine, iodine, and astatine that form part of Group VII A of the periodic table and exist in the free state normally as diatomic molecules
HCl	hydrochloric acid
IRP	Installation Restoration Program
IRPIMS	Installation Restoration Program Information Management System
ITC	International Technology Corporation
K	potassium
McClellan AFB	McClellan Air Force Base
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
Mg	mercury

MicroFem	a steady-state, finite-element computer modeling program used to evaluate capture of contaminants for certain groundwater flow conditions and pumping rates at extraction wells
MLU	a computer modeling program that creates a transient, multiaquifer simulation that uses a least squares, curve-fitting algorithm to calculate aquifer and aquitard parameters based on time-drawdown data collected during aquifer tests
msl	mean sea level
Na	sodium
NAAQS	National Primary and Secondary Ambient Air Quality Standards
NCP	National Oil and Hazardous Substances Contingency Plan
NO ₂	nitrogen dioxide
NOAEL	no observed adverse effect level
NO _x	oxides of nitrogen
NO ₂	nitrogen dioxide
NPDES	National Pollutant Discharge Elimination System
NSPS	New Source Performance Standards
NSR	new source review
O&M	operation and maintenance
O ₂	oxygen
offgas	the airstream discharged from a soil vapor extraction system. Before being released to the atmosphere, this contaminated airstream will require some form of treatment to remove the contamination.
offgas treatment components	At the Davis Site, four treatment possibilities were evaluated: electron beam technology, catalytic oxidation, gas phase carbon adsorption, and synthetic resin adsorption systems
OSHA	Occupational Safety and Health Act
P	phosphorus
PADRE	Purus adsorption desorption remediation material
PCE	perchloroethene or tetrachloroethene
PID	photoionization detector

PM10	particulate matter less than 10 microns in diameter
PNAs	polynuclear aromatic compounds (semi-volatile compounds)
POHC	principle organic hazardous constituent
pore volume	volume of all the air in the soil pore spaces within the region of contamination
pore volume exchange	one complete replacement of air in all the pores of soil in a specified area with uncontaminated air
psia	pounds per square inch atmospheric
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
QAPP	quality assurance project plan
QC	quality control
RAP	Remedial Action Program
RCRA	Resource Conservation and Recovery Act
RfD	reference dose, usually expressed in units of mg/kg-day
RI	remedial investigation
RI/FS	remedial investigation/feasibility study
RME	reasonable maximum exposure
ROD	Record of Decision
ROG	reactive organic gas
RPDs	relative percent differences
RWQCB	Regional Water Quality Control Board
SAP	sampling and analysis plan
SARA	1986 Superfund Amendments and Reauthorization Act
SCOCs	subset of contaminants of concern
SCS	Soil Conservation Service
SDG	sample delivery group
SDWA	Safe Drinking Water Act

SMAQMD	Sacramento Metropolitan Air Quality Management District
SO ₂	sulfur dioxide
soil gas	gas present in soils
sorbed	attached or held
sorption	the process of sorbing; taking up and holding as by adsorption or absorption
SOV	soil organic vapor survey
SPT	standard penetration test
STLC	soluble threshold limit concentration
Stripper	a computer program designed to calculate design parameters for an air stripping column based on detailed conditions and treatment objectives of the specified site
SVE	soil vapor extraction
SVMW	soil vapor monitoring well
SWRCB	State Water Resources Control Board
target volumes	the target area multiplied by the thickness of each respective zone. There are two target volumes. Target Volume 1 consists of contamination present above the C-D aquitard. Target Volume 2 consists of all known contamination from the land surface down to the bottom of the E aquifer.
TBACT	toxic best available control technology
TBCs	to-be-considered criteria
1,1,1-TCA	1,1,1-trichloroethane
TCD	thermal conductivity detector
TCE	trichloroethene
TCLP	toxicity characteristic leaching procedure
TFH	total fuel hydrocarbon
THMs	trihalomethanes
TOC	total organic carbon
TPH	total petroleum hydrocarbons

trans-1,2-DCE	trans-1,2-dichloroethene
TSCA	Toxic Substances Control Act
TTLc	total threshold limit concentration
TVOCs	total volatile organic compounds
UBC	Uniform Building Code
UFSTs	underground fuel storage tanks
USDA	U.S. Department of Agriculture
USDA/SCS	U.S. Department of Agriculture/Soil Conservation Service
UTV	unit target volume—the volume of air or water that is contained within a respective target volume; it represents a single pore air or pore water exchange
UV	ultraviolet
vadose zone	soils above the water table
VCL	vinyl chloride
VLEACH	a computer modeling program designed to simulate the leaching of volatile contaminants through the vadose zone.
VOCs	volatile organic compounds
volatilization	the act of evaporating or causing to be evaporated
WDR	waste discharge requirements
YSAPCD	Yolo/Solano Air Pollution Control District



Chapter 1 Introduction

This Remedial Investigation/Feasibility Study (RI/FS) report was produced by CH2M HILL for McClellan Air Force Base (McClellan AFB) as a portion of Delivery Order 5055, under Contract No. F04699-90-D-0035.

The purpose of this RI/FS report is to document the current understanding of the contamination problem at the Davis Global Communications Site (Davis Site) and to evaluate possible actions that could be taken to mitigate the problem. A summary of field investigation activities undertaken from 1985 to the present are presented in this report. Data generated from this fieldwork are subject to hydrogeologic and engineering evaluations, which are used to develop a hydrogeologic model of the site and to develop hypotheses regarding the nature and extent of contamination. These data evaluations then provide the basis for developing and comparing different remedial action alternatives for the Davis Site.

Data used in these evaluations include all soil, soil gas, and groundwater data available at the time the report was prepared through February 1993. Water quality data for July 1993 were available in draft form in October 1993. These data were incorporated into site cross sections and into the development of target areas and volumes in Chapter 4. Groundwater modeling was performed to verify extraction well placement, extraction rates, and capture zones for the recommended remedial action. Groundwater modeling results are presented in Appendix J.

This report has been prepared to comply with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) guidance for conducting RI/FS work. However, the Davis Site is technically not a CERCLA site. The California Environmental Protection Agency is the lead regulatory agency. The decision to prepare a study that complies with CERCLA was made voluntarily by McClellan AFB.

Steps in the RI/FS process:

- *Identify data needs*
- *Perform investigation*
- *Interpret data*
- *Characterize site*
- *Develop and evaluate remedial action alternatives*
- *Select preferred remedy*

1.1 Focus and Structure of the RI/FS Report

A workshop was held on June 30, 1993, between CH2M HILL staff, McClellan AFB staff, and representatives from the State of California Department of Toxic Substances Control (DTSC) and the Regional Water Quality Control Board (RWQCB) to achieve consensus on the appropriate focus and structure of this RI/FS report. During the workshop, a list of questions that would be answered in the report, along with the best methods to be used for answering the RI/FS questions regarding

contamination problems at the Davis Site were identified. This RI/FS report has been designed to answer the important questions regarding contamination at the Davis Site using the presentation and analysis methods discussed in the workshop.

Consensus was also obtained on a variety of other issues at the June 30 workshop, including remedial response objectives, methodology for addressing the petroleum hydrocarbon contamination, role of the risk assessment, and approach to the FS. These items are summarized in this section.

1.1.1 Remedial Response Objectives

The following remedial response objectives were identified for the Davis Site:

- Reduce or eliminate levels of subsurface contamination that pose a potential threat to human health or the environment.
- Prevent the spread of groundwater contamination beneath the site, especially to regional aquifers.
- Provide implementable strategies for remedial actions as quickly as possible and still maintain compliance with the Federal Facilities Site Remediation Agreement (FFSRA) Schedule.

The remedial actions that are eventually undertaken at the Davis Site will be required to satisfy the above objectives.

1.1.2 Methodology for Addressing the Petroleum Hydrocarbon Contamination

Petroleum hydrocarbon contamination exists at the Davis Site as a result of diesel fuel that was discharged through three leaking underground storage tanks. The tanks were removed in 1988, but contamination remains.

The zone of petroleum hydrocarbon contamination is currently the subject of a bioventing treatability study being conducted by Engineering Science, Inc. The treatability study is scheduled to be complete by September 1994.

Characterization of the zone of petroleum hydrocarbon contamination was part of the remedial investigation, and discussion regarding the extent of this zone of contamination and the impacts that this zone may have on the fate and transport of other contamination in the subsurface is included in the RI portion of this report. However, as agreed to in the workshop, a detailed evaluation of cleanup options that could be used to remediate the petroleum hydrocarbon contamination is not included in the FS. Rather a separate less detailed evaluation comparing bioventing with the excavation cleanup option is presented in Appendix K, Hydrocarbon Remediation Options.

The reason for doing this is twofold. First, the effectiveness of bioventing at the Davis Site is currently unknown because treatability data are not yet available; therefore, a full evaluation and comparison of bioventing with other options cannot be completed until the treatability data are available. Secondly, remedial alternatives that address other contaminant types at the Davis Site (e.g., volatile organic compounds [VOCs] in soil and groundwater) can be evaluated and compared using available data; remedial actions can be selected and implemented for these contaminant types without the need to wait for completion of the bioventing treatability study. This will allow other contaminated media to begin remediation earlier than would otherwise be possible if the FS was not completed until the bioventing treatability data became available.

1.1.3 Role of the Risk Assessment in the Remedial Investigation/Feasibility Study Program

A risk assessment document is being prepared as a separate deliverable in tandem with this RI/FS report. The role of the risk assessment at the Davis Site is to: (1) identify the contaminants of concern (COCs), (2) identify reasonable exposure pathways, and (3) estimate the risks associated with each pathway.

As discussed in the workshop, the exposure pathways that are considered by the risk assessment are inhalation of VOCs from the soil gas, exposure to contaminants from the site production well, and exposure to VOCs in the groundwater. According to DTSC, metals exposure will be excluded from risk analysis because historic site activities indicate that there is no reason to suspect metals contamination.

1.1.4 Approach to the Feasibility Study

During the June 30 workshop, cleanup options to be evaluated in the FS were defined. Possible options were developed separately for the vadose zone and the groundwater, as listed:

Vadose Zone Cleanup Options

- No-Action
- Soil Vapor Extraction

Groundwater Cleanup Options

- No-Action
- Groundwater Extraction

Each of the above cleanup options has different treatment and end-use components that were included in the FS evaluation. These are presented in Chapter 6 of this RI/FS report. In addition, for groundwater two different target volumes that represent different regions of capture were considered. These are also described in Chapter 6.

At the request of McClellan AFB and the state agencies, this report also discusses and evaluates an innovative extraction method for the vadose zone and groundwater contamination referred to as dual-phase extraction.

This method allows contaminated water and air to be extracted from the same well.

1.2 Site History

The Davis Site is an annex of McClellan AFB in Sacramento, located approximately 4 miles south of the City of Davis (as shown in Figure 1-1). The site was built in the 1950s and covers approximately 316 acres in Yolo County and is surrounded by farmland. A 320-acre parcel located adjacent to the west portion of the site was ceded to Yolo County in 1973 for development as Wilson Park. Currently, part of Wilson Park is leased to an archery club, a horseshoe club, and a dog training club. The remainder is open grassland.

The Davis Site consists of the fenced, Main Compound Area (approximately 8 acres shown in Figure 1-2), communication antennas, and undeveloped grasslands. The Davis Site is staffed with approximately 12 people 24 hours a day by the 2049th Communications Squadron, which operates out of McClellan AFB, approximately 20 miles to the northeast.

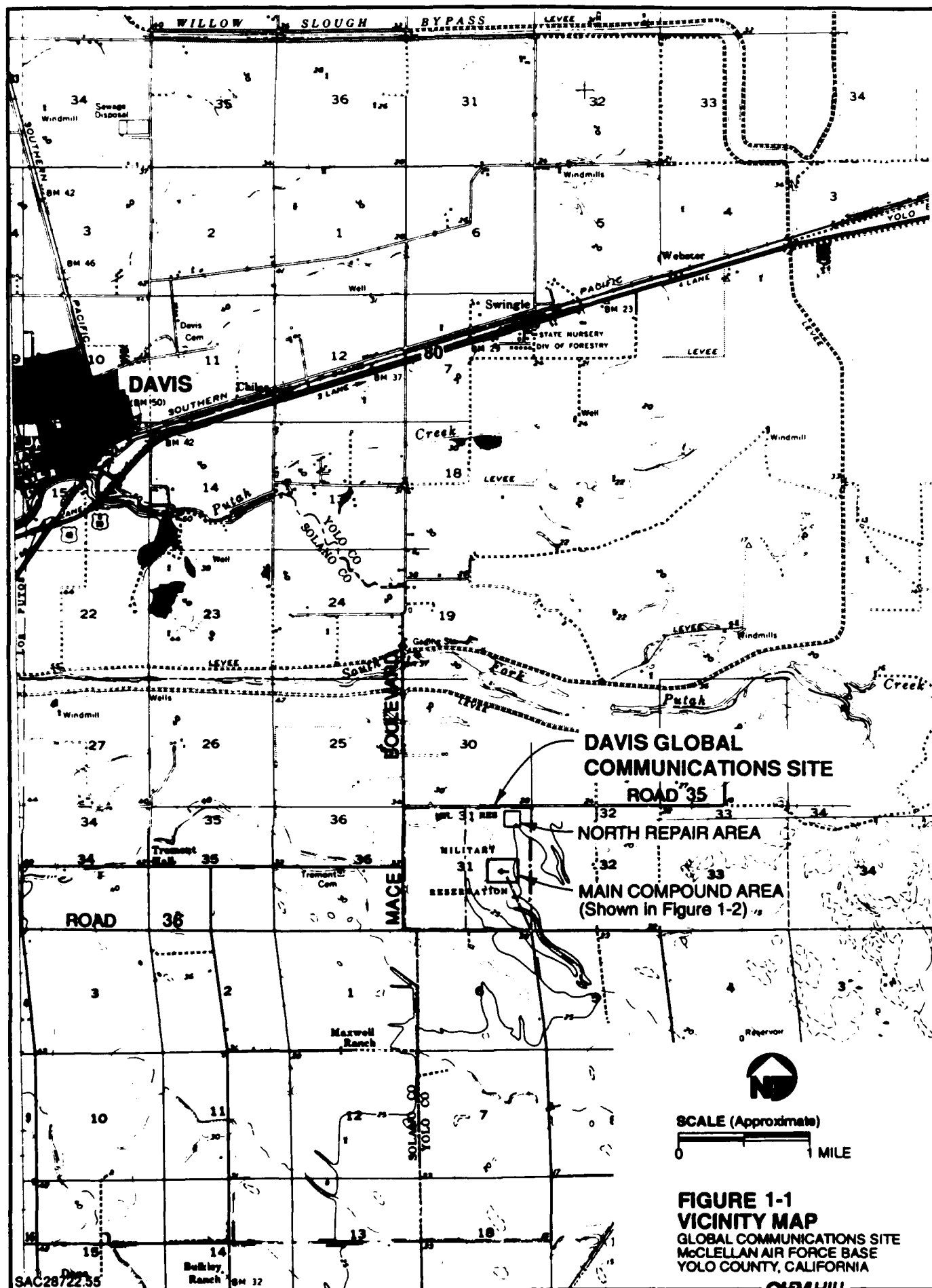
In 1985, three underground storage diesel-fuel tanks and associated piping were discovered to be leaking diesel fuel. The tanks were drained and removed in 1988. However, during the course of the field investigation for hydrocarbon contamination, VOCs were detected in groundwater samples. The source of these VOCs is unknown. However, it is likely that past surface disposal practices of spent solvents contributes to the contamination problem. Figure 1-3 (shown on page 1-7) is a time-line illustrating contractors that have worked at the Davis Site since 1985. Further details of investigation activities are presented in Chapter 2 and in the appendixes.

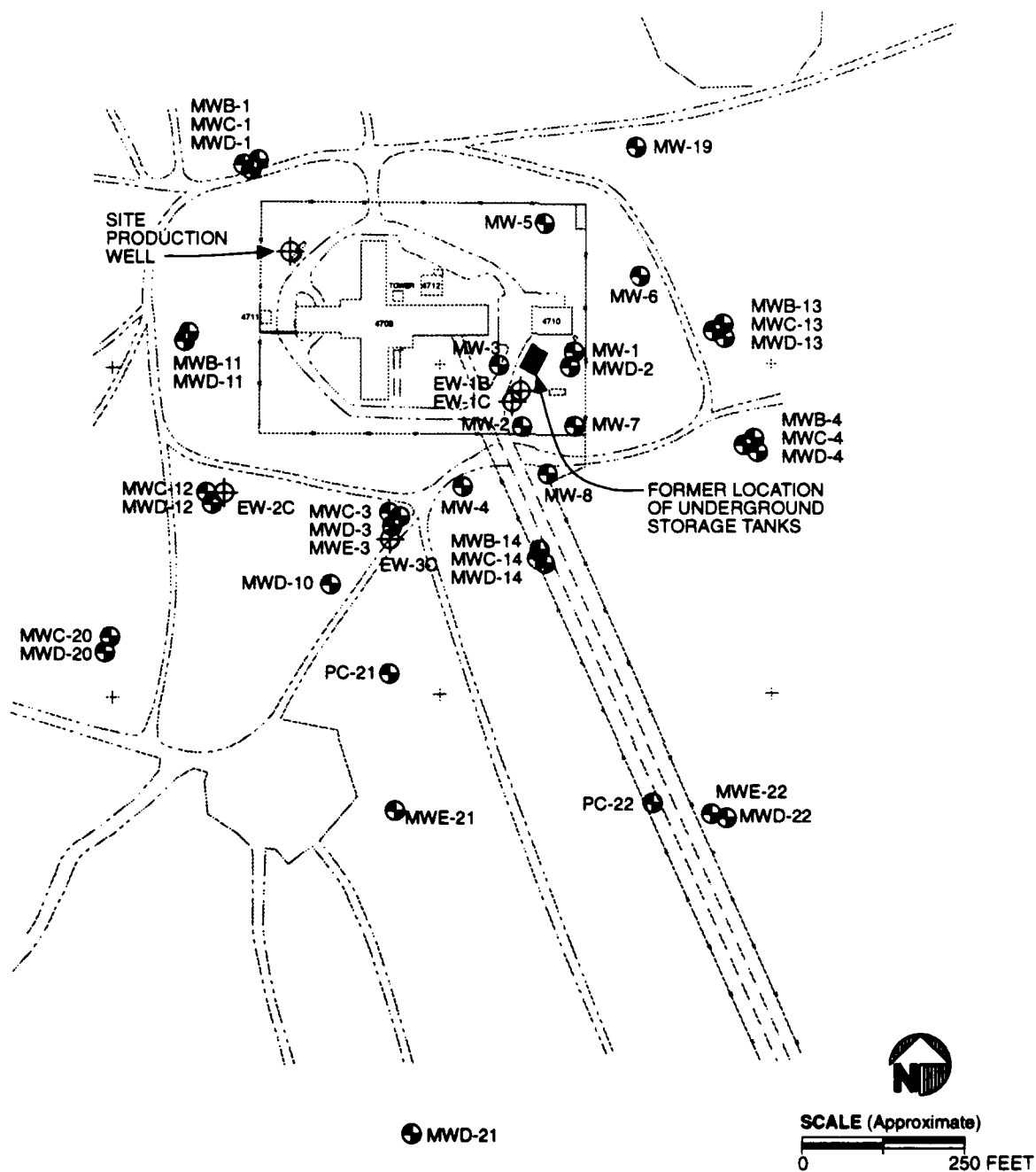
1.3 Remedial Investigation/Feasibility Study Objectives

1.3.1 Remedial Investigation Objectives

The principle objective of the RI is to compile sufficient data to perform a feasibility study, develop a remedial design, and implement a remedial action. This objective is divided into specific vadose zone and groundwater objectives. The vadose zone objectives are:

- Identify areas of soil gas contamination within or near the Davis Site.
- Identify changes in soil gas concentrations over time.
- Provide quantitative information on contaminants mass in shallow soil.

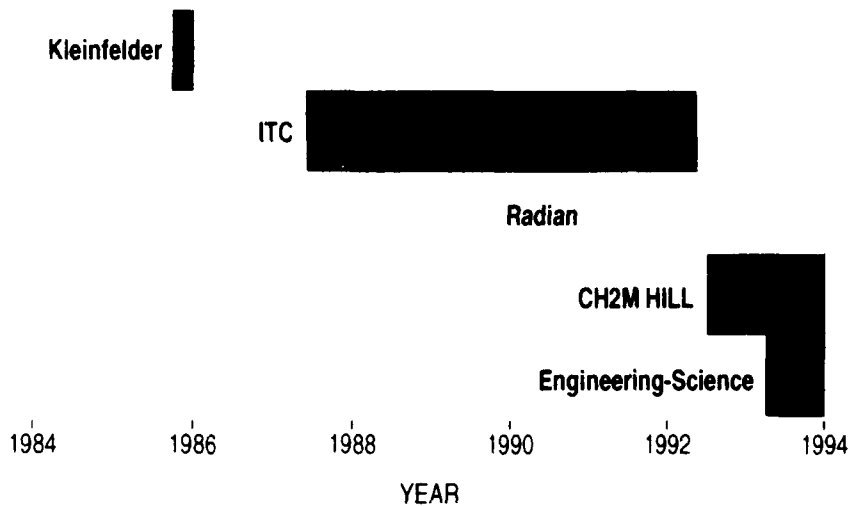




SITE MAP

Showing former underground storage tank
location and monitoring well locations.

FIGURE 1-2
DAVIS SITE MAP
DAVIS GLOBAL COMMUNICATIONS SITE
McCLELLAN AIR FORCE BASE
YOLO COUNTY, CALIFORNIA



**FIGURE 1-3
TIME-LINE OF RI CONTRACTORS
AT THE DAVIS SITE**

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- Identify areas where additional soil gas information is needed.
- Conduct soil sampling to quantify levels of petroleum hydrocarbons and the vertical distribution of contaminants observed to be hot spots during the soil gas survey.
- Install soil vapor monitoring wells

Groundwater objectives are summarized as follows:

- Develop a description of the site hydrogeology that is consistent with previous interpretations and that incorporates recent findings.
- Characterize nature of both coarse- and fine-grained units to estimate their potential to act as aquifers and aquitards, respectively.
- Characterize seasonal variation in flow direction and vertical and horizontal hydraulic gradients in contaminated aquifers.
- Investigate the extent of contamination in the B aquifer north of the northeast corner of the Main Compound Area.
- Investigate the seasonal variation in water quality in the B aquifer.
- Investigate the extent of contamination in the C, D, and E aquifers.

1.3.2 Feasibility Study Objectives

The objectives of the Feasibility Study portion of this RI/FS report are as follows:

- Identify and describe potential remedial action alternatives that could be used to clean up the contamination.
- Evaluate and compare the different remedial action alternatives so that decisionmakers can see the benefits and shortcomings of each alternative.
- Identify emerging innovative remediation techniques that are not ready for implementation today, but could be ready for application of the Davis Site in the near future.

These objectives are designed to support the decisionmakers in developing the remedial action plan (RAP) for the Davis Site.

1.4 Contaminants of Concern

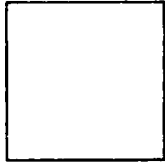
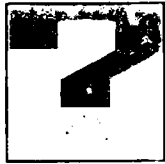
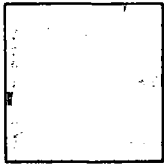
Table 1-1 summarizes the contaminants of concern for the Davis site. This list was developed based on risk assessment analysis, as summarized in the risk assessment report for the site (CH2M HILL, 1993a). As shown in the table, the COCs are subdivided based on whether they are a problem in the vadose zone, a problem in the groundwater, or a problem in both. The following criteria were used to develop the COCs list:

1. A contaminant was considered a COC if it contributed to 1 percent or more of the total site risk according to the risk assessment evaluation.
2. Contaminants in the groundwater were considered COCs if their concentrations exceeded drinking water standards.
3. Contaminants in the vadose zone were considered COCs if they had the potential to contaminate groundwater in the future via downward migration.

Some of the COCs listed in Table 1-1 are probably not derived from Davis Site operations and their discharge. For example, ethylene dibromide (EDB) is a common soil fumigant used for agricultural purposes and is likely derived from agricultural activity near the site. In addition, the trihalomethane contaminants (THMs) are probably created after the water from the production well is subject to chlorination, and are not frequently detected in situ in the groundwater. However, all identified contaminants of concern are listed here because they all have the potential to impact human health. A subset of COCs was generated for the vadose zone and groundwater. This subset, the SCOCs, is evaluated in Chapter 4, Nature and Extent of Contamination.

Table 1-1 Contaminants of Concern			
Compound	Contaminant of Concern in Vadose Zone	Contaminant of Concern in Groundwater	Comments
1,1-Dichloroethane	x	x	Exceeds drinking water standards in groundwater.
1,1-Dichloroethene	x	x	Exceeds drinking water standards in groundwater.
1,1,1-Trichloroethane	x	x	Contributes greater than 1 percent of total site risk.
1,1,2-Trichloro-1,2,2-trifluoro- ethane		x	Detected in site production well above drinking water standards.
1,4-Dichlorobenzene		x	Detected in site production well above drinking water standards.
2-methylnaphthalene	x		Possible constituent of diesel-range petroleum hydrocarbons in soil. It has the potential to migrate to groundwater.
Acetone		x	Detected in site production well above drinking water standards.
Benzene	x	x	Exceeds drinking water standards in groundwater. Possible constituent of diesel-range petroleum hydrocarbons in soil.
Bis(2-ethylhexyl)phthalate	x		Source unknown. Typical laboratory contaminant. If it exists, it has the potential to migrate to groundwater.
Bromodichloromethane		x	Exceeds drinking water standards in site production well. Not typically detected in monitoring wells.
Bromofom		x	Exceeds drinking water standards in site production well. Not typically detected in monitoring wells.
Butylbenzylphthalate	x		Source unknown. Typical laboratory contaminant. If it exists, it has the potential to migrate to groundwater.
Chlorodibromomethane		x	Exceeds drinking water standards in site production well. Not typically detected in monitoring wells.
Chlorofom		x	Exceeds drinking water standards in site production well. Not typically detected in monitoring wells.
cis-1,2-dichloroethene		x	Exceeds drinking water standards in groundwater.
Di-n-butylphthalate	x		Source unknown. Typical laboratory contaminant. If it exists, it has the potential to migrate to groundwater.
Dibenzofuran	x		Possible constituent of diesel-range petroleum hydrocarbons in soil. It has the potential to migrate to groundwater.
Ethylbenzene	x		Possible constituent of diesel-range petroleum hydro- carbons in soil. It has the potential to migrate to groundwater.
Ethylene dibromide (EDB)		x	Detected in site production well above drinking water standards. Occurrence likely to be associated with agricultural pesticide use and not related to site activities.
Fluorene	x		Possible constituent of diesel-range petroleum hydrocarbons in soil. It has the potential to migrate to groundwater.
m- and p-xylenes	x	x	Possible constituent of diesel-range petroleum hydrocarbons in soil. It has the potential to migrate to groundwater.
Methyl isobutyl ketone		x	Detected in site production well above drinking water standards.

Table 1-1 Contaminants of Concern			
Compound	Contaminant of Concern in Vadose Zone	Contaminant of Concern in Groundwater	Comments
Methyl ethyl ketone		x	Detected in site production well above drinking water standards.
Naphthalene	x		Possible constituent of diesel-range petroleum hydrocarbons in soil. It has the potential to migrate to groundwater.
o-xylene	x	x	Possible constituent of diesel-range petroleum hydrocarbons in soil. It has potential to migrate to groundwater.
Petroleum hydrocarbons	x	x	Possible constituent of diesel-range petroleum hydrocarbons in soil. Petroleum hydrocarbon detected in groundwater above drinking water standards near underground storage tank site.
Phenanthrene	x		Possible constituent of diesel-range petroleum hydrocarbons in soil. It has the potential to migrate to groundwater.
Pyrene	x		Possible constituent of diesel-range petroleum hydrocarbons in soil. It has the potential to migrate to groundwater.
Tetrachloroethene (PCE)	x	x	Exceeds drinking water standards in groundwater. Contaminant in soil is a potential source for continuing contaminant release to groundwater.
Toluene	x	x	Possible constituent of diesel-range petroleum hydrocarbons in soil. It has the potential to migrate to groundwater.
trans-1,2-dichloromethene		x	Exceeds drinking water standards in groundwater.
Trichloroethene (TCE)	x	x	Exceeds drinking water standards in groundwater.
Trichlorofluoromethane		x	Detected in site production well above drinking water standards.
Vinyl chloride	x	x	Exceeds drinking water standards in groundwater.



Chapter 2 Field Investigation Activities

This chapter includes a summary of all remedial investigation activities performed at the Davis Site since 1985. This information will be presented in the following four forms and will be divided into the three media analyzed (soil, groundwater, and soil gas):

- The chapter will begin with a brief written description of the field activities.
- A map of the Davis Site will be used as a base for overlays showing sampling or other field activity locations, in terms of media.
- A flow chart will present field activities in chronological order, in terms of media.
- A table will be used to present the sampling activities in chronological order in terms of the three media.

2.1 Summary of Previous Field Investigations

Ten borings drilled by J. H. Kleinfelder & Associates in 1985 identified soil contamination in the vicinity of three underground diesel fuel tanks. The tanks were exposed, and damage to at least one tank and associated piping was evident. The tanks were then drained and covered with clean fill dirt and were removed in 1988.

In 1987, an investigation performed by International Technology Corporation (ITC) confirmed the presence of hydrocarbon contamination in the vicinity of the storage tanks to a depth of 55 feet below ground surface (bgs) and determined that the groundwater beneath the site had been contaminated with volatile organic compounds (VOCs) (Radian Corporation, 1990). This investigation included seven additional soil borings and installation of eight groundwater monitoring wells.

In subsequent investigations by ITC, trichloroethene (TCE) and tetrachloroethene (PCE) were found in vapors collected from soil vapor surveys to depths of 10 feet and in groundwater as deep as 225 feet bgs. These investigations included 19 Cone Penetrometer Test (CPT) soundings, 11 soil borings, Hydropunch sampling at CPT locations, installation of 17 additional monitoring wells, and a soil gas survey.

Summary of Previous Investigations

99	<i>Soil Gas Points</i>
9	<i>CPT Soundings</i>
30	<i>Hydropunch Soundings</i>
28	<i>Soil Borings</i>
29	<i>Groundwater Wells</i>
11	<i>Tank Pull Samples</i>

2.2 Summary of Current Field Investigations

CH2M HILL has conducted field investigation activities since June 1992. A detailed summary of field activities is included in Appendix D, Summary of Field Activity. Field activities include the following:

- Dry or partially submerged groundwater monitoring wells, MW-1, MW-3, MW-5, and MW-7, were sampled for soil gas in August 1992.
- Aquifer testing was conducted on Monitoring Wells MWC-3, MWC-12, and MWC-14 in August 1992. During January 1993, additional aquifer tests were performed on Monitoring Wells MWD-12 and MW-3.
- A total of 71 shallow soil gas samples were collected in September and October 1992 from depths ranging from 5 to 20 feet bgs to assist in the location of soil vapor monitoring wells (SVMWs). Details are provided in Appendix A, Soil Gas Investigation.
- Ex situ soil piles were sampled for petroleum hydrocarbons in November 1992.
- Six CPT soundings (CPT-18, CPT-18A, CPT-20, CPT-21, CPT-22, and CPT-23) were performed in November 1992 to investigate site stratigraphy.
- Five SVMWs (CH-1 through CH-5) and adjacent piezometers (P-1S and P-1D, P-2M, P-3S and P-3D, P-4S and P-4D, P-5S and P-5D) were installed in November 1992 to investigate the vadose zone chemical and hydrogeologic properties. Selected soil samples were submitted for analytical and physical testing.
- SVMWs and adjacent shallow piezometers were sampled for VOCs, and air permeability tests were performed in December 1992 to provide estimates of hydraulic conductivity in the vadose zone. Details are provided in Appendix A and in Appendix B, Air Permeability Testing.
- Four groundwater extraction wells (EW-1B, EW-1C, EW-2C, and EW-3C) were installed in April and May 1993 to capture contaminated groundwater from the B and C aquifers.
- Seven new groundwater monitoring wells (MW-19, MWC-20, MWD-20, MWD-21, MWE-21, MWD-22, and MWE-22) and two groundwater piezometers (PC-21 and PC-22) were installed in May and June 1993 to aid in estimating the nature and extent of groundwater contamination.
- Short duration pump tests were performed during well development to estimate aquifer properties of the new extraction wells and monitoring wells.

Summary of Current Investigations

71	Soil Gas Points
8	CPT Soundings
5	SVMWs
12	Piezometers
11	Groundwater Monitoring Wells
14	Soil Pile Samples
5	Aquifer Tests

- Two CPT soundings (CPT-24 and CPT-25) were advanced in April 1993, and a test hole (TH-1) was drilled in May 1993 to provide guidance for locating a proposed injection well. The test hole was core sampled, logged (geologically and geophysically), and tremied with grout in June 1993.
- Groundwater levels were measured biweekly during 1992 and monthly during 1993.
- Groundwater levels were collected on an hourly basis from Well Cluster MW1 from July 1992 to July 1993.

Table 2-1 provides a summary of the three media sampled during remedial investigations (soil, groundwater, and soil gas). Within each media the activities are listed in chronological order.

Table 2-2 contains well construction data for the SVMWs and piezometers and groundwater monitoring wells at the Davis Site.

Figure 2-1 is a detailed chronology of field investigation activities conducted at the Davis Site since 1985. The activities are divided into three portions: soil, groundwater, and soil gas. Also provided is the name of the contractor performing the field activity.

Figures 2-2 and 2-3 are base maps for Overlay Figures 2-2a through 2-2d, and 2-3a. The overlays include sampling locations or other field activity shown in Figure 2-1. Because there is a high degree of overlap in sampling locations, these overlays were developed so that sampling locations can be viewed in various combinations. Each overlay has a set of match points along the southern edge of the site. These match points should overlap when using the overlays (removing the overlays and base map from the binder may simplify their use). Sampling locations for the activities summarized in Figure 2-1 are included in these overlays and are organized as follows:

- Figures 2-2a and 2-2b include locations related to soil sampling activities.
- Figures 2-2c and 2-2d include locations related to groundwater sampling activities.
- Figures 2-3a includes locations related to soil gas sampling activities. (ITC's 1989 shallow soil gas sampling locations are shown on the basemap, Figure 2-3.)

Other field investigation activities currently being conducted at the Davis Site are being performed by Radian Corporation and Engineering-Science Inc. Radian is responsible for quarterly groundwater sampling from the monitoring wells onsite. This sampling has been performed on a quarterly basis since July 1992. Historical groundwater quality data are contained in Appendix U, Historical Contaminant Data. Engineering-Science, Inc. is performing a treatability study using in situ bioventing to remediate hydrocarbon contamination.

Table 2-1

Summary of Field Investigation Activities

Description Activity	Designation	Total Depth (feet bgs)	Analyses Performed	Contractor (Date Sampled)	Reference
SOIL (Soil Borings, CPT Soundings, Soil Sampling during Drilling of Monitoring Wells, and Sampling of Soil Piles)					
1. B- Series Soil Borings	B-1 through B-10	38.5 to 56.5	EPA418.1 (TPH) SW8240 (VOCs)	Kleinfelder (10/87)	ITC
2. BB- Series Soil Borings	BB-11 through BB-17	71.5 to 84.5	SW8015 (TFH Diesel) SW8020 (BTEX)	ITC (8/87-9/87)	ITC
3. Soil Samples Collected from MW- Series Monitoring Wells	MW-1 through MW-8	80.5 to 84.0	EPA 602 (BTEX) SW8015 (TFH Diesel) SW8020 (BTEX)	ITC (9/87-10/87)	ITC
4. Tank Pull Grab Samples	EM3952 through EM3963	Not Measured	SW6010 (ICP Metals) SW8010 (VOCs) SW8015 (TFH Diesel) SW8020 (BTEX) SW8270 (Semi VOCs)	McClellan (5/88)	ITC
5. 1st Round CPT Soundings	CPT-1 through CPT-4 and PCPT-1 through PCPT-5	119 to 125	Not Applicable	ITC (5/89)	ITC
6. Stratigraphic Soil Borings	THD-1 through THD-4	280	Geophysical Logging	ITC (4/89)	ITC
7. MWD-Well Borings	THD-11 through THD-14	300	Geophysical Logging	ITC (11/90)	
8. SBB- Series Soil Borings	SBB-18 through SBB-24	155.5	SW8015 (TFH Diesel) SW8240 (VOCs)	ITC (12/89)	ITC
9. 2nd Round CPT Soundings	PCPT-6, -7, and -10 through -17	48 to 168	Not Applicable	ITC (1/90)	
10. Soil Samples Collected from SVM	CH-1 through CH-5	61.5 to 71.5	ASTM D 2216 (Moisture Content) ASTM D 2937 (Bulk Density) ASTM D (Specific Gravity) EPA 418.1 (TPH) SW6010 (ICP Metals) SW7421 (Lead) SW7471 (Mercury) EPA 415.1M (TOC)	CH2M HILL (11/92)	CH2M HILL

Table 2-1

Summary of Field Investigation Activities

Description Activity	Designation	Total Depth (feet bgs)	Analyses Performed	Contractor (Date Sampled)	Reference
11. Grab Samples from Ex Situ Soil	ESP-1 through ESP-9 and NSP-1A, NSP-1B, NSP-2A, NSP-2B, and NSP-3	0 to 1	EPA 418.1 (TPH) SW8015 (TFH Diesel)	CH2M HILL (11/92)	CH2M HILL
12. Cone Penetrometer Soundings	CPT-18 through CPT-23	50 to 100	NA	CH2M HILL (11/92)	CH2M HILL
13. Cone Penetrometer Soundings	CPT-24 through CPT-25	72 to 73	NA	CH2M HILL (4/93)	CH2M HILL
14. Soil Samples from Extraction Well	EW-1C	81 to 83	EPA8020/8010 (VOCs/BTEX)	CH2M HILL (5/93)	CH2M HILL
15. Test Hole for ReInjection Well	TH-1	270	Geophysical Logging	CH2M HILL (6/93)	CH2M HILL
WATER (Groundwater Sampling from Monitoring Wells and Hydropunch)					
16. MW- Series Wells	MW-1 through MW-8	58 to 81	SW8015 (TFH Diesel)	ITC (10/87, 1/88, 4/88, 8/88, 11/88)	IRPMS
17. 1st Phase Hydropunch	PCPT(H)-2 through PCPT (H)-5	38 to 118	SW8010 (VOCs) SW8020 (BTEX)	ITC (5/89)	ITC
18. 2nd Phase Hydropunch	H-10 through H-17	72 to 110	SW8010 (VOCs) SW8020 (BTEX)	ITC (1/90)	ITC
19. Cluster Wells (21 wells)	MWB-1, -4, -11, -13, -14 MWC-1, -3, -4, -12, -13, -14 MWD-1, -2, -3, -4, -10, -11, -12, -13, -14 MWE-3	66 to 89 93 to 110 127 to 181 204 to 224	SW8010 (VOCs) SW8015 (TFH Diesel) SW8020 (BTEX)	ITC (5/90 to 1/91)	ITC
20. MW- Series	See Above, No. 16		SW8010 (VOCs) SW8015 (TFH Diesel) SW8020 (BTEX)	ITC (2/91)	ITC
21. Quarterly Sampling	All wells listed in Nos. 15 and 16 (with exceptions advised by ITC)		SW8010 (VOCs) SW8015 (TFH Diesel) SW8020 (BTEX)	Radian (1/91, 5/91)	Radian

Table 2-1

Summary of Field Investigation Activities

Description Activity	Designation	Total Depth (feet bgs)	Analyses Performed	Contractor (Date Sampled)	Reference
22. Remedial Investigation Wells	PC-21, PC-22	82 to 101	NA	Drilled by CH2M HILL (4/93 to 5/93)	CH2M HILL
	MW-19, EW-1B	50 to 100			
	MWC-20, EW-1C, EW-2C, EW-3C	72 to 141			
	MWD-20, MWD-21, MWD-22	143 to 167			
	MWE-21, MWE-22	196 to 218			
23. Hydropunch	HP-2	72	SW8010 (VOCs)	CH2M HILL 6/93	CH2M HILL
24. Quarterly Sampling	All Wells in Nos. 15, 18, and 21		SW8010 (VOCs)	Radian (7/92, 10/92, 2/93, 4/93, 7/93)	CH2M HILL and Radian
			SW8015 (TFH Diesel)		
			SW8020 (BTEX)		
SOIL GAS (Shallow Soil Gas Sampling, SVMWs, and Groundwater Wells Sampled for Soil Gas)					
25. 1st Phase Soil Gas Sampling	MC-1 through MC-67, PW-1, PW-2, PW-10 and NR-1 through NR-29 (94 samples)	10	Analyzed using PhotoVac tip or analyzed for TCE, PCE, VCL, and benzene using a mobile lab using nonstandard methods	ITC (4/89)	ITC
26. Shallow Soil Gas Sampling	SG-1 through SG-46 (67 samples)	5, 10, and 20	SW8021 (VOCs using Mobile GC) TO14 (VOCs using GCMS)	CH2M HILL (9/92)	CH2M HILL
27. Risk Assessment Samples	RA-01 through RA-04	5-20	SW8021 (VOCs using Mobile GC) TO14 (VOCs using GCMS)	CH2M HILL (9/92)	CH2M HILL
28. Sampling SVMWs and selected Groundwater Monitoring Wells and Piezometers	CH-1 through CH-6	14-38	TO14 (VOCs using GCMS) D3416 ATM Gases	CH2M HILL (12/92)	CH2M HILL
	MW-1, MW-3, MW-5, MW-7 P-1S, P-2M, P-3S, P-4S, P-5S	14-20			
29. Sampling Deep Piezometers	P-1D, P-3D, P-4D	40 to 60	TO14 (VOCs using GCMS)	CH2M HILL (8/93)	Results Pending
Notes: ITC (ITC, Appendix E, 1992) CH2M HILL (CH2M HILL RI/FS, 1993) IRPIMS (Installation Restoration Program Information Management System, January 1991) Radian (Radian, 1993)					

Table 2-2

Well Construction Data

Well	Date Completed	Ground Surface Elevation (feet)	TOD Elevation (feet)	Well Diameter (inches)	Well Casing Material	Screen Material/Slot Size	Screened Interval (feet lbs)
Soil Vapor Monitoring Wells and Piezometers							
CH-1	11 12 92	26.64	28.70	2	PVC Sch. 40	PVC Sch. 40 0.03	25 to 35
P-1S	11 12 92	26.61	27.29	1	PVC Sch. 40	PVC Sch. 40 0.04	14 to 16
P-1D	11 12 92	26.61	27.62	1	PVC Sch. 40	PVC Sch. 40 0.04	48 to 58
CH-2	11 23 92	26.18	28.18	2	PVC Sch. 40	PVC Sch. 40 0.04	14 to 16
P-2M	11 23 92	26.13	27.54	1	PVC Sch. 40	PVC Sch. 40 0.04	30 to 35
CH-3	11 19 92	25.78	27.83	2	PVC Sch. 40	PVC Sch. 40 0.03	22 to 32
P-3S	11 19 92	25.82	27.48	1	PVC Sch. 40	PVC Sch. 40 0.04	15 to 17
P-3D	11 19 92	25.82	27.21	1	PVC Sch. 40	PVC Sch. 40 0.04	48 to 58
CH-4	11 23 92	25.57	28.34	2	PVC Sch. 40	PVC Sch. 40 0.03	27 to 37
P-4S	11 23 92	25.53	27.67	1	PVC Sch. 40	PVC Sch. 40 0.04	17 to 19
P-4D	11 23 92	25.53	27.73	1	PVC Sch. 40	PVC Sch. 40 0.04	45 to 55
CH-5	11 24 92	28.68	28.49	2	PVC Sch. 40	PVC Sch. 40 0.03	28 to 38
P-5S	11 24 92	28.65	28.37	1	PVC Sch. 40	PVC Sch. 40 0.04	18 to 20
P-5D	11 24 92	28.65	28.36	1	PVC Sch. 40	PVC Sch. 40 0.04	45 to 55
B Aquifer							
MW-1	9 23 87	28.46	27.42	4	PVC Sch. 40	SS304 0.02	61 to 81
MW-2	9 25 87	28.10	26.88	4	PVC Sch. 40	SS304 0.02	61 to 81
MW-3	9 20 87	29.86	28.82	4	PVC Sch. 40	SS304 0.02	61 to 81
MW-4	9 3 87	26.58	27.08	4	PVC Sch. 40	SS304 0.02	58 to 78
MW-5	9 18 87	26.88	26.47	4	PVC Sch. 40	SS304 0.02	59 to 79
MW-6	9 11 87	25.26	25.94	4	PVC Sch. 40	SS304 0.02	59 to 79
MW-7	9 30 87	27.50	27.02	4	PVC Sch. 40	SS304 0.02	61 to 81
MW-8	10 2 87	26.50	26.88	4	PVC Sch. 40	SS304 0.02	60 to 80
MW-19	5 26 93	25.53	25.98	4	PVC Sch. 40	SS304 0.02	71 to 81
MWB-1	11 1 90	29.74	32.55	4	PVC Sch. 40	SS304 0.02	75 to 85
MWB-4	11 6 90	24.69	26.98	4	PVC Sch. 40	SS304 0.02	66 to 76
MWB-11	1 11 91	26.82	29.25	4	PVC Sch. 40	SS304 0.02	72 to 82
MWB-13	12 21 90	24.97	27.39	4	PVC Sch. 40	SS304 0.02	74 to 79
MWB-14	1 7 91	26.35	28.89	4	PVC Sch. 40	SS304 0.02	79 to 89
EW-1B	5 5 93	29.11	28.89	4	PVC Sch. 40	SS304 0.035	50 to 100
C Aquifer							
MWC-1	11 5 90	29.74	32.01	4	PVC Sch. 40	SS304 0.02	95 to 105
MWD-2	4 12 90	28.14	27.87	4	PVC Sch. 80	SS 304 0.02	127 to 137
MWC-3	1 9 91	26.94	29.16	4	PVC Sch. 40	SS304 0.02	93 to 103

G:\users\da emr\drawings\TAB2-2.XLS

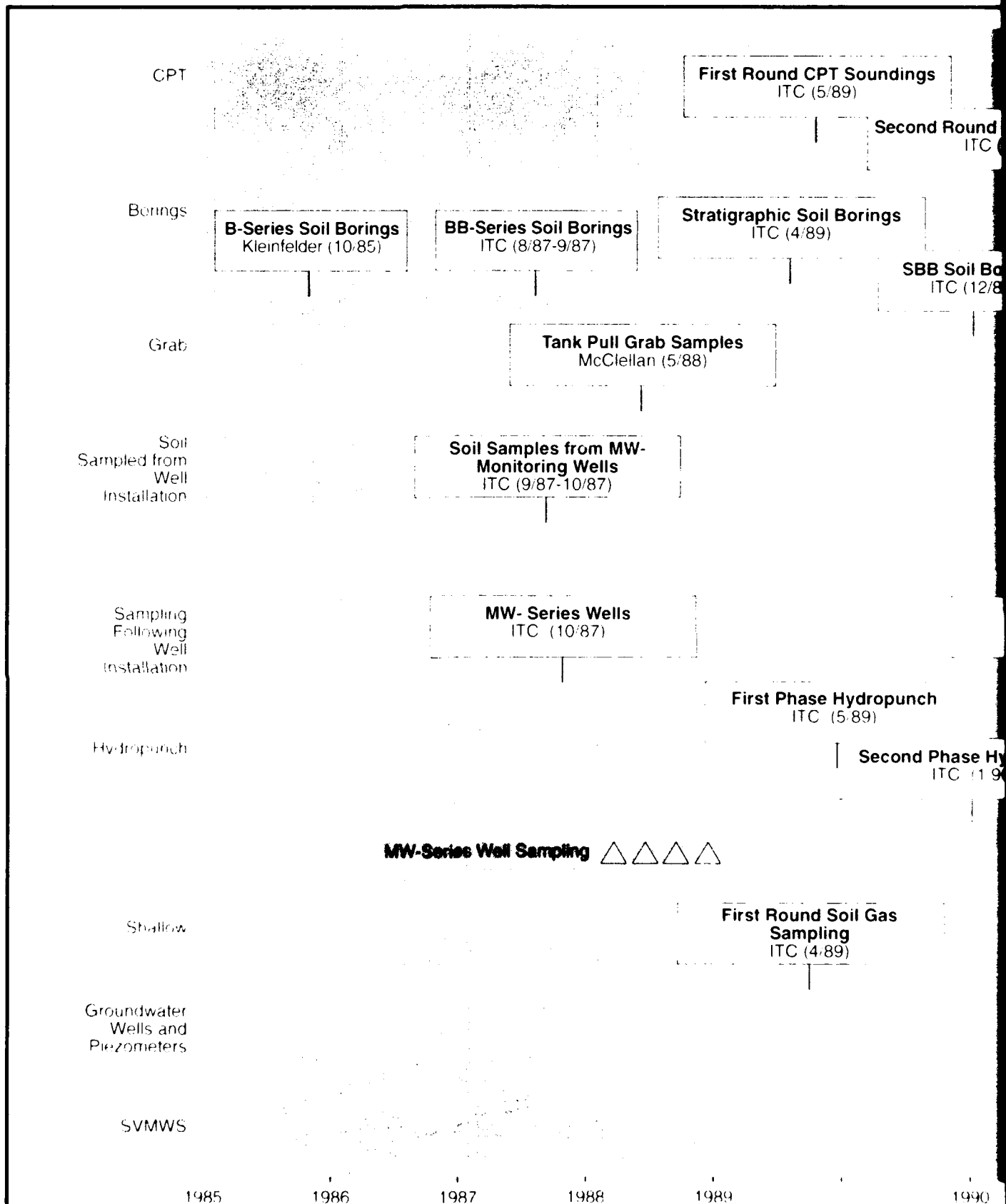
Table 2-2
Well Construction Data

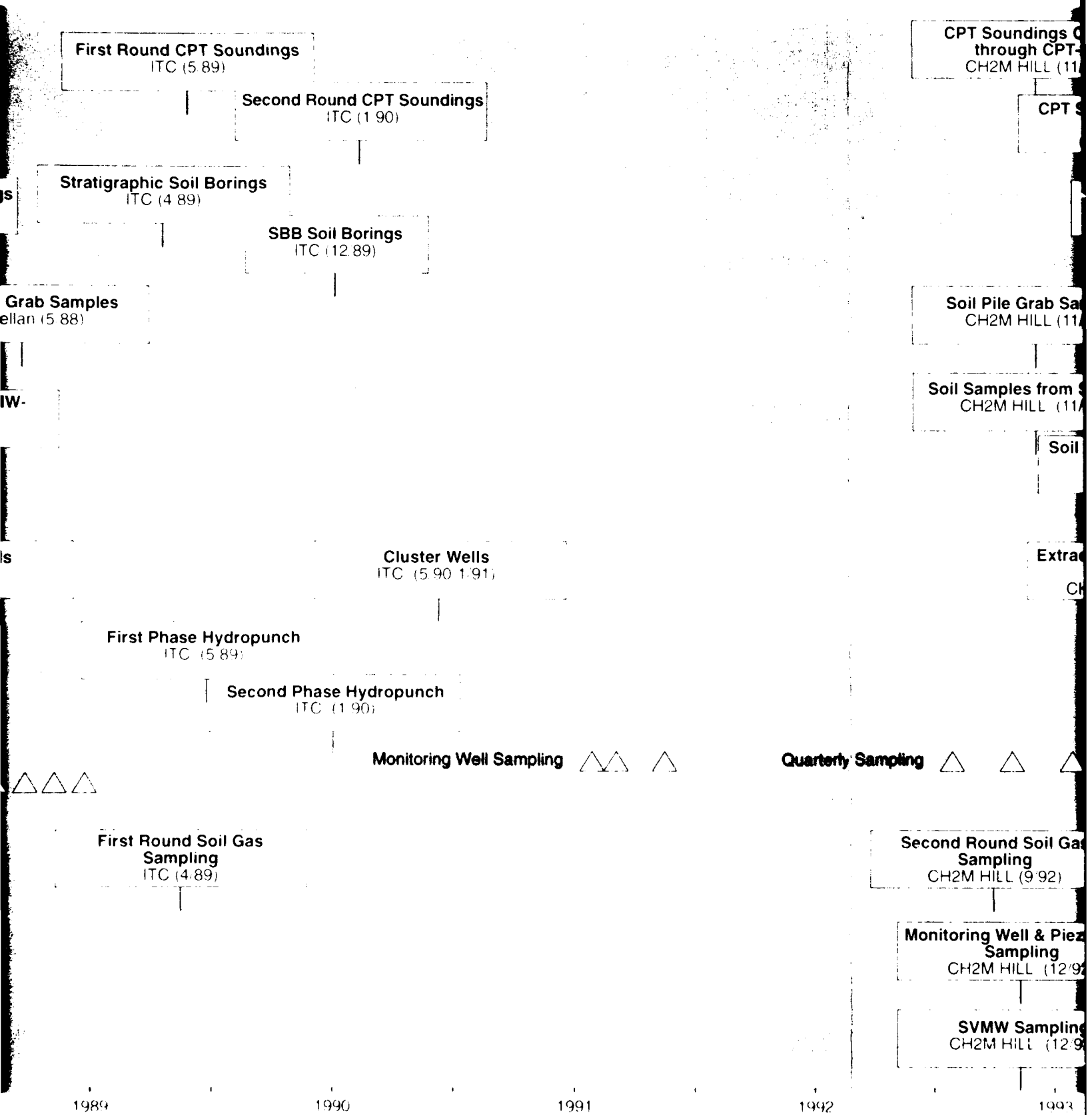
Well	Date Completed	Ground Surface Elevation (feet)	TWC Elevation (feet)	Well Diameter (inches)	Well Casing Material	Screen Material/ Slot Size	Screened Interval (feet bgs)
NWC-4	11 8 90	24.64	27.57	4	PVC Sch. 40	SS304 0.02	95 to 105
NWC-12	12 7 90	28.25	30.69	4	PVC Sch. 40	SS304 0.02	99 to 109
NWC-13	1 31 91	25.11	27.49	4	PVC Sch. 40	SS304 0.02	100 to 110
NWC-14	1 15 91	26.25	28.69	4	PVC Sch. 40	SS304 0.02	96 to 106
NWC-20	6 10 93	NM*	31.75	4	PVC Sch. 40	SS304 0.02	88 to 108
PC-21	4 28 93	NM	27.96	4	PVC Sch. 40	SS304 0.02	82 to 92
PC-22	5 1 93	NM	28.11	4	PVC Sch. 40	SS304 0.02	91 to 101
EW-1C	5 4 93	29.07	28.74	6	PVC Sch. 80	SS304 0.035	130 to 140
EW-2C	4 30 93	NM	29.48	6	PVC Sch. 80	SS304 0.035	78 to 108
EW-3C	4 28 93	NM	28.59	6	PVC Sch. 80	SS304 0.035	93 to 108
D Aquifer							
MWD-1	4 3 90	30.20	31.90	4	PVC Sch. 80	SS304 0.02	152 to 162
MWD-3	4 25 90	27.06	28.68	4	PVC Sch. 80	SS304 0.02	155 to 175
MWD-4	4 27 90	25.01	26.50	4	PVC Sch. 80	SS304 0.02	160 to 170
MWD-10	12 3 90	27.02	29.22	5	PVC Sch. 80	SS304 0.02	162 to 172
MWD-11	12 13 90	27.42	29.29	5	PVC Sch. 80	SS304 0.02	171 to 181
MWD-12	1 18 91	28.27	30.82	5	PVC Sch. 80	SS304 0.02	165 to 175
MWD-13	11 9 90	24.97	27.30	5	PVC Sch. 80	SS304 0.02	186 to 196
MWD-14	12 18 90	26.33	28.57	5	PVC Sch. 80	SS304 0.02	149 to 169
MWD-20	5 28 93	NM	30.34	5	PVC Sch. 80	SS304 0.02	143 to 163
MWD-21	6 7 93	NM	29.16	5	PVC Sch. 80	SS304 0.02	148 to 168
MWD-22	6 2 93	NM	26.65	5	PVC Sch. 80	SS304 0.02	147 to 167
E Aquifer							
MWE-3	12 3 90	26.82	29.72	5	PVC Sch. 80	SS304 0.02	204 to 224
MWE-21	5 17 93	NM	29.92	5	PVC Sch. 80	SS304 0.02	196 to 216
MWE-22	5 21 93	NM	26.51	5	PVC Sch. 80	SS304 0.02	198 to 218

* - MWD-2 is screened within the C aquifer. In future CH2M HILL documents, this well will be referred to as MWC-2.

Notes:

NM - Not Measured





**FIGURE 2-1
CHRONOLOGY**
DAVIS GLOBAL COMM
MCLELLAN AIR FORCE
YOLO COUNTY, CALIF

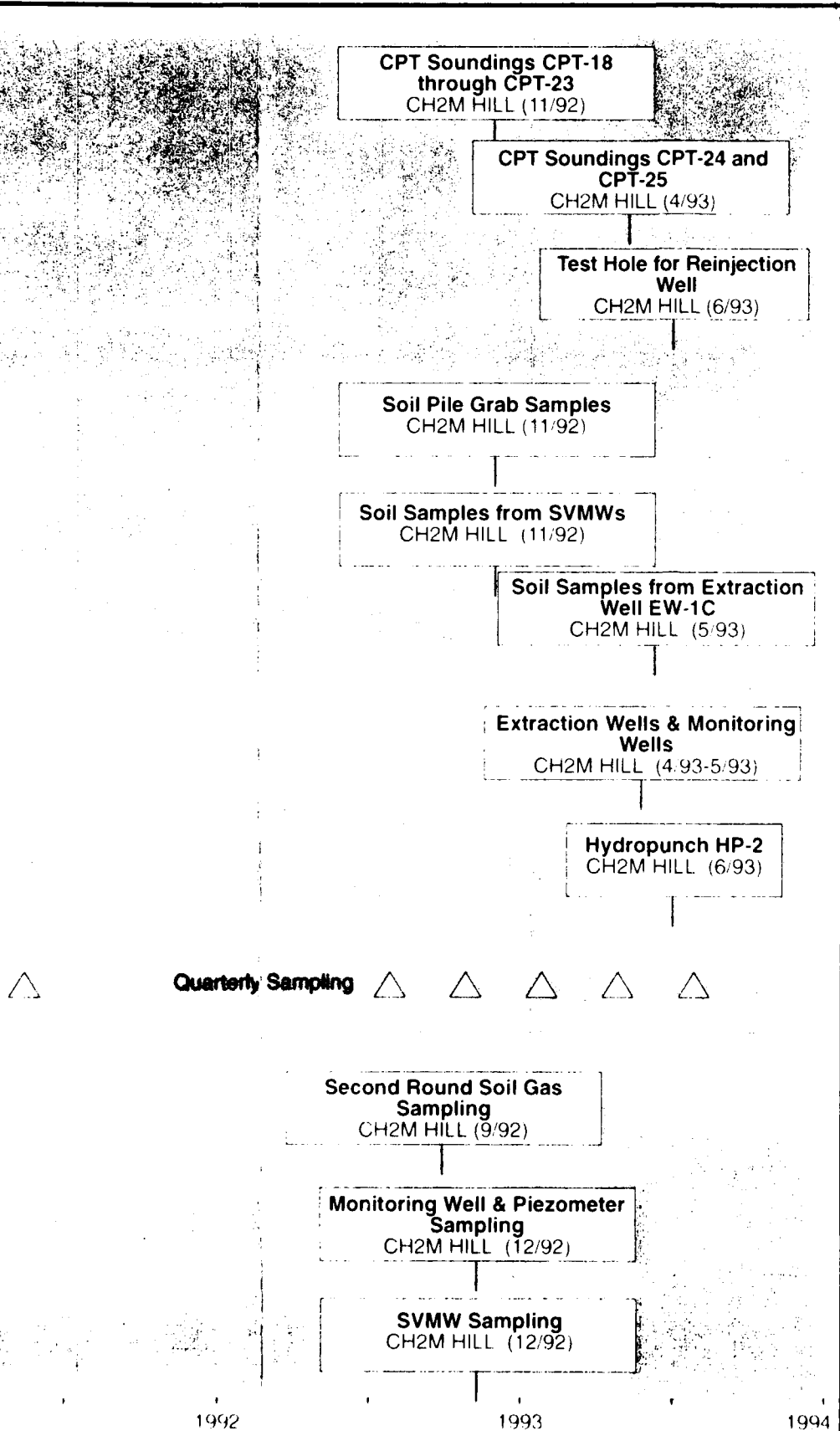


FIGURE 2-1
CHRONOLOGY OF FIELD ACTIVITIES
DAVIS GLOBAL COMMUNICATIONS SITE
MCLELLAN AIR FORCE BASE
YOLO COUNTY, CALIFORNIA

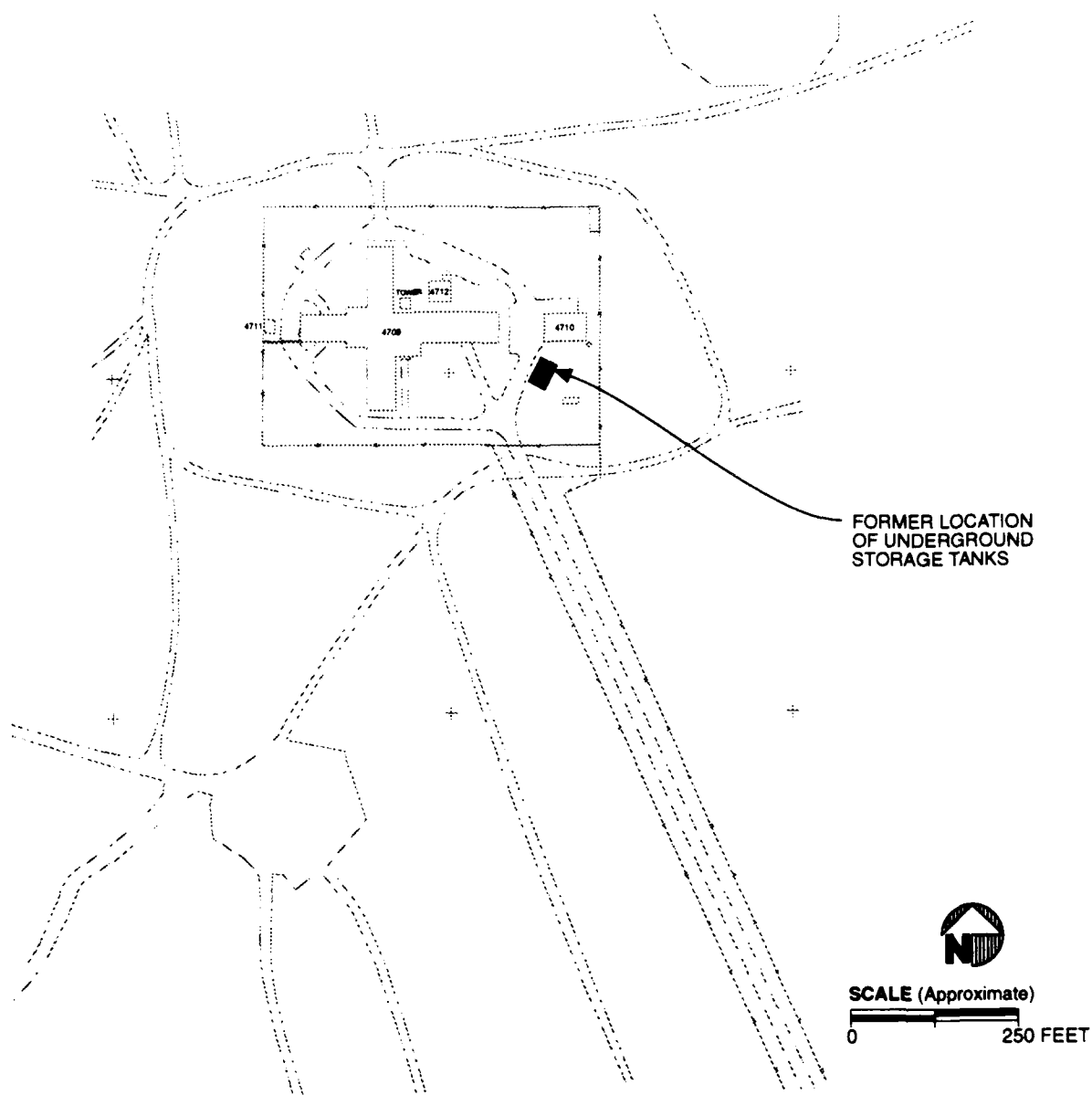
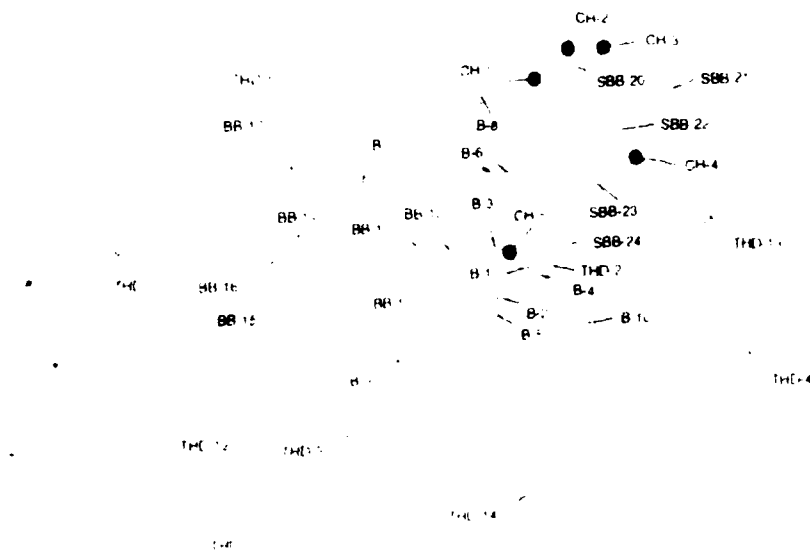


FIGURE 2-2
BASE MAP FOR
SAMPLING LOCATIONS
DAVIS GLOBAL COMMUNICATIONS SITE
McCLELLAN AIR FORCE BASE
YOLO COUNTY, CALIFORNIA



LEGEND

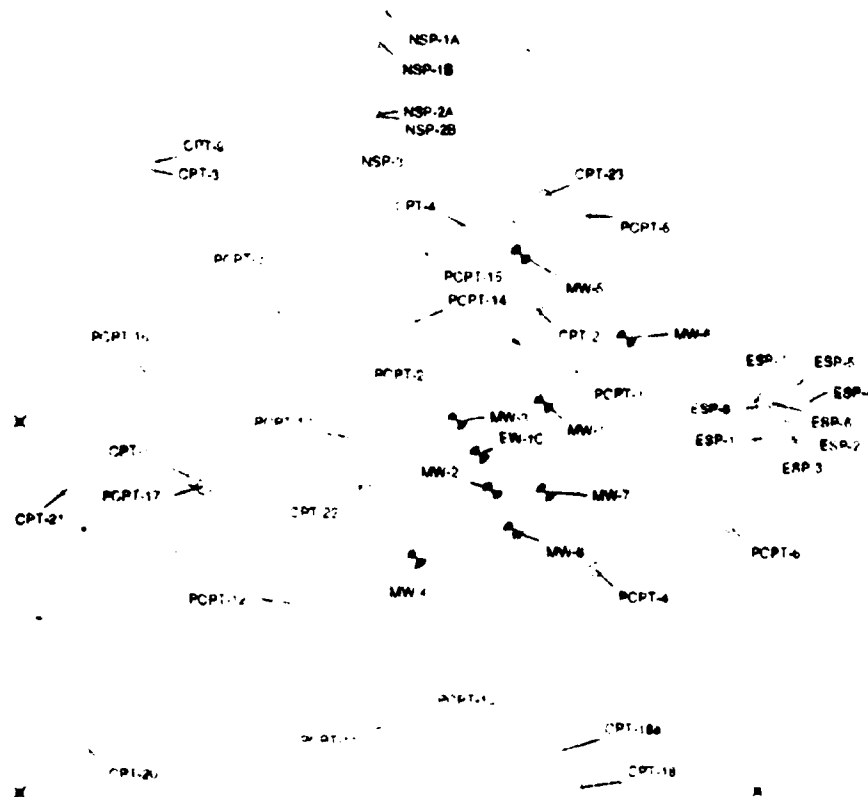
SOIL BORINGS

- B-1 through B-10 (Kleinfelder, 1985)
- BB-11 through B-17 (ITC, August through September 1985)
- SBB-18 through SBB-24 (ITC, December 1990)
- THD-1 through THD-4 (ITC, November 1990, Geophysical Logs)
- THD-11 through THD-14 (ITC, November 1990, Geophysical Logs)

- SOIL VAPOR MONITORING WELL SAMPLED FOR SOIL
- CH-1 through CH-5 (CH2M HILL, November 1992)

NOTE Locations based on IRPIMS data

FIGURE 2-2a
SOIL SAMPLING LOCATIONS
 DAVIS GLOBAL COMMUNICATIONS SITE
 McCLELLAN AIR FORCE BASE
 YOLO COUNTY CALIFORNIA



LEGEND

CONE PENETROMETER SOUNDINGS

CPT-1 through CPT-4 (ITC, May 1989)
 PCPT-1 through PCPT-5 (ITC, May 1989)
 PCPT-6 through PCPT-7 (ITC, January 1990)
 PCPT-10 through PCPT-17 (ITC, January 1990)
 CPT-9 (ITC, January 1990)
 CPT-18, CPT-18a, CPT-20 through CPT-23 (CH2M HILL, November 1992)

GROUNDWATER MONITORING WELL SAMPLED FOR SOIL
 MW-1 through MW-8 (ITC, August 1987)
 EW-1C (CH2M HILL, May 1988)

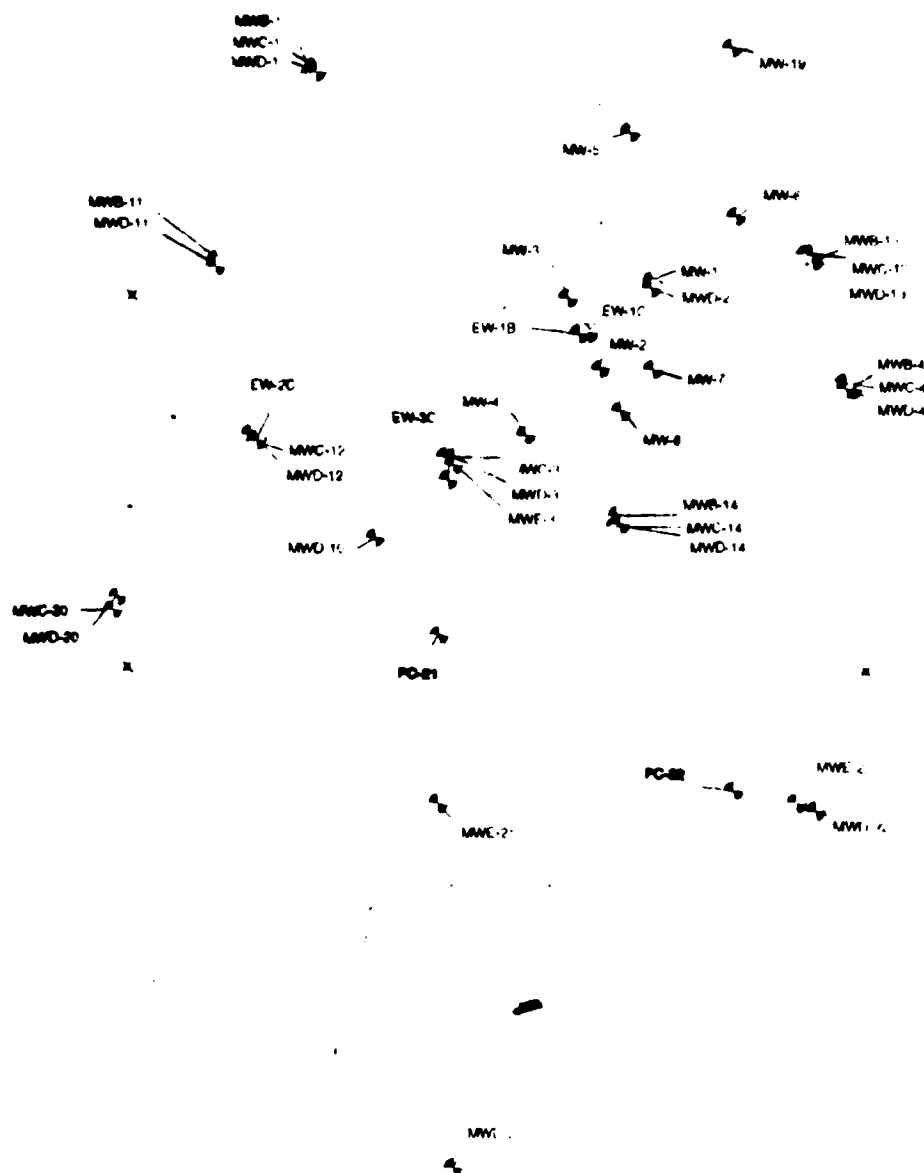
EX SITU SOIL PILES

ESP-1 through ESP-6; NSP-1A, -1B; NSP-2A, -2B; NSP-3
 (CH2M HILL, November 1992)

FIGURE 2-2b CONE PENETROMETER SOUNDINGS AND GROUNDWATER WELLS SAMPLED FOR SOIL

DAVIS GLOBAL COMMUNICATIONS SITE
 MCCLELLAN AIR FORCE BASE
 YOLO COUNTY, CALIFORNIA

NOTE: Locations based on IRPIMS data



LEGEND

- GROUNDWATER MONITORING WELL**

MW-1 through MW-8 (ITC, August 1987)

Cluster Wells: MWB-1, -4, -11, -13, -14; MWC-1, -3, -4, -12, -13, -14;

MWD-1, -2, -3, -4, -10, -11, -12, -13, -14; MWE-3

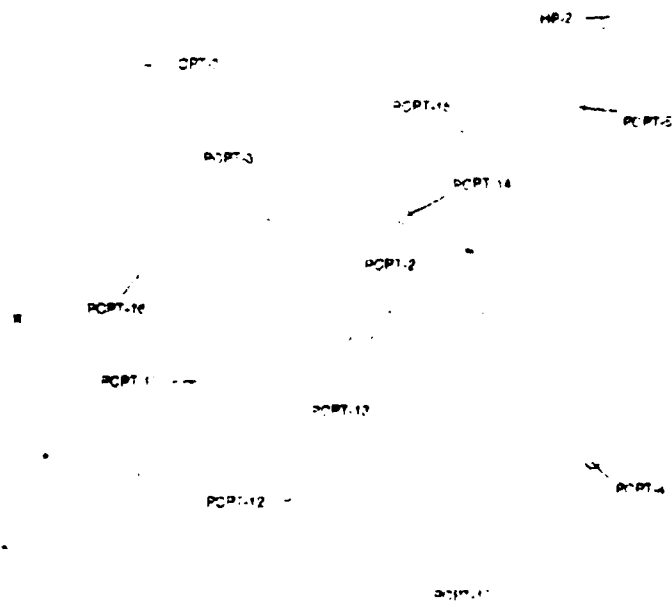
(ITC, October through January 1991)

MW-19, MWC-20, MWD-20, -21, -22; MWE-21, -22; and Piezometers PC-21,

PC-22 (CH2M HILL, April through June 1993)
- EXTRACTION WELL**

EW-1B, EW-1C, EW-2C, EW-3C (CH2M HILL, April through May 1993)

FIGURE 2-2c
GROUNDWATER
SAMPLING LOCATIONS
 DAVIS GLOBAL COMMUNICATIONS SITE
 McCLELLAN AIR FORCE BASE
 YOLO COUNTY, CALIFORNIA



LEGEND

CONE PENETROMETER SOUNDINGS

CPT-3, PCPT-2 through PCPT-5 (ITC, May 1989)

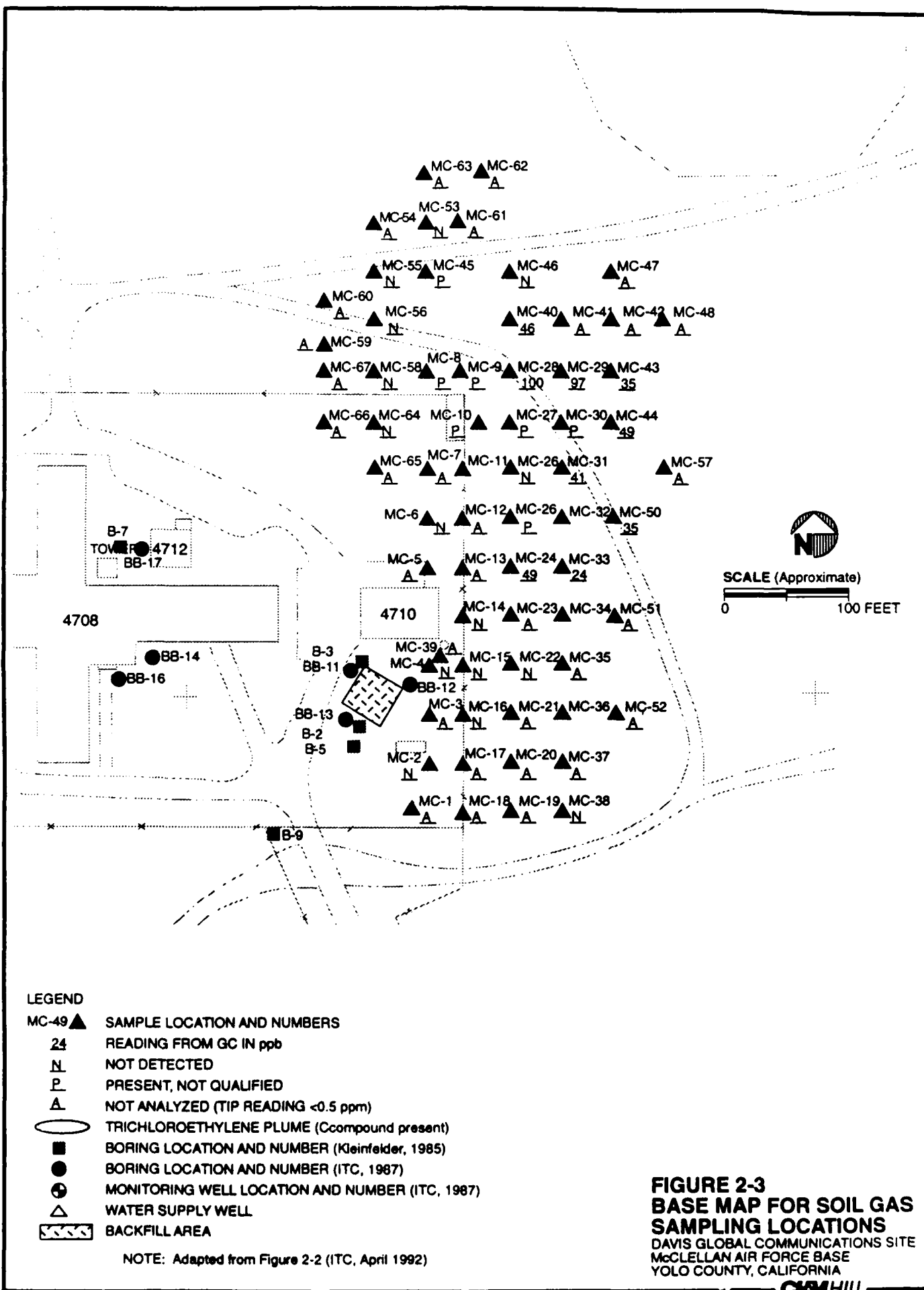
PCPT-10, PCPT-12 through PCPT-17 (ITC, January 1990)

HYDROPUNCH

HP-2 (CH2M HILL, April 1989)

TE: Hydropunch samples were taken at the sounding locations

FIGURE 2-2d
HYDROPUNCH LOCATIONS
 DAVIS GLOBAL COMMUNICATIONS SITE
 MCCLELLAN AIR FORCE BASE
 YOLO COUNTY, CALIFORNIA





Chapter 3 Hydrogeologic Conditions

In order to develop an understanding of the hydrogeology at the Davis Site and build hypotheses for contaminant transport and potential site remedial actions, the data generated from the remedial investigation (RI) are interpreted in this chapter.

3.1 Regional Hydrogeology

The regional hydrogeology helps explain the interaction between site conditions (e.g., water levels) and regional influences. Results of the RI show that irrigation withdrawals from the regional aquifer system greatly effect groundwater flow beneath the Davis Site. A good understanding of the interaction between the regional and local hydrogeologic systems is critical in evaluating site risk, contaminant transport and potential corrective actions.

3.1.1 Geology

The freshwater-bearing sediments in the vicinity of the Davis Site consist of three geologic units listed from ground surface to increasing depth and age—the younger alluvium, the older alluvium, and the Tehama Formation (USGS, 1960). The younger alluvium is up to 40 feet thick consisting primarily of fine-grained flood plain or overbank deposits mixed with lesser amounts of sandy stream channel deposits. The older alluvium is 60 to 130 feet thick and consists of stream deposits of silt, silty clay, gravel, and sand deposited by Putah Creek. Fine-grained deposits predominate. Gravel and sand deposits comprise about one-fourth the thickness and occur as discontinuous lenses rather than continuous sheets. The Tehama Formation occurs below about 160 feet and is over 2,000 feet thick. It consists of silt, clay, and silty fine sand enclosing lenses of sand and gravel and silt and gravel. The geologic contact with the older alluvium is poorly defined, difficult to determine in borings, and may be gradational.

3.1.2 Groundwater Levels and Flow Directions

Regional and local vertical and horizontal groundwater gradients are influenced by agricultural pumping during the growing season from April to October. Groundwater levels typically fluctuate 30 feet or more per year, and there are strong downward gradients during the growing season caused by pumping agricultural wells in the vicinity of the site, which are typically 200 to 500 feet deep. Most agricultural wells are screened from 150 feet within the D and lower aquifers. Winter groundwater levels approach mean sea level (msl) while summer levels drop to lower than -40 feet msl. During recharge in the winter, gradients are slightly upward. Prior to agricultural development, groundwater flowed eastward from the Coast Range toward the discharge point at the Sacramento River

east of the site. A groundwater pumping depression has existed for over 60 years near Dixon, California, southwest of the site, which causes regional gradients in the vicinity of the site to be primarily toward the south-southwest rather than east (see Figure 3-1).

3.2 Site Hydrogeology

Lithologic data from past investigations have been reviewed and incorporated into current lithologic data to develop hypotheses on the subsurface conditions beneath the Davis Site. Uncertainties remain regarding the extent of aquifers and their associated hydraulic properties. The effects of these uncertainties on site remedial actions are discussed in more detail in Chapter 6.

3.2.1 Stratigraphy

The stratigraphy underlying the site has been divided into five zones—A, B, C, D, and E. These zones are made up of coarse-grained and fine-grained materials. For convenience in discussion, the terms "B," "C," "D," and "E" aquifer have been retained and apply to the permeable units within each specific zone. The five zones extend to a depth of approximately 245 feet below the site. While the depth and thickness of all zones varies within the area of contamination, stratigraphic borings indicate that generally these zones exist as they have been shown in the cross sections in Chapter 4. The conceptual cross section shown in Figure 3-2 indicates the location of these zones beneath the site.

The zones include both permeable aquifer materials (sand and gravel) and low permeability aquitard materials (silt and clay). The low permeability zones, which generally exist across the site between aquifers, are termed aquitards and have been named the A-B, B-C, C-D, and D-E aquitards. The A zone (vadose zone) extends from ground surface to 65 feet below ground surface (bgs) and contains the A-B aquitard; the B zone extends from 65 to 95 feet bgs and contains the B aquifer; the C zone extends from 95 to 145 feet bgs and contains the B-C aquitard and the C aquifer; the D zone extends from 145 to 195 feet bgs and contains the C-D aquitard and the D aquifer; and the E zone extends from 195 to 245 feet bgs and contains the D-E aquitard and the E aquifer.

A conceptual cross section is shown in Figure 3-2. The horizontal scale has been exaggerated to allow subsurface features to be shown more clearly.

The conceptual cross section depicts the depositional history of the site and how this may lead to the pattern of groundwater contamination found beneath the site. Coarse-grained deposits within 150 feet of the surface are a result of sandy stream channel deposition mixed with fine-grained flood plain deposits. The stream channel deposits are more uniform and continuous in a generally north-south direction probably the result of ancient Putah Creek meandering. Discontinuities within the coarse-grained deposits are more prevalent in the east-west direction than the north-south direction supporting this hypothesis.

Vadose Zone	A-B Aquitard	0
B Zone	B Aquifer	65
C Zone	B-C Aquitard C Aquifer	95
D Zone	D-C Aquitard D Aquifer	145
E Zone	D-E Aquitard E Aquifer	195
		245

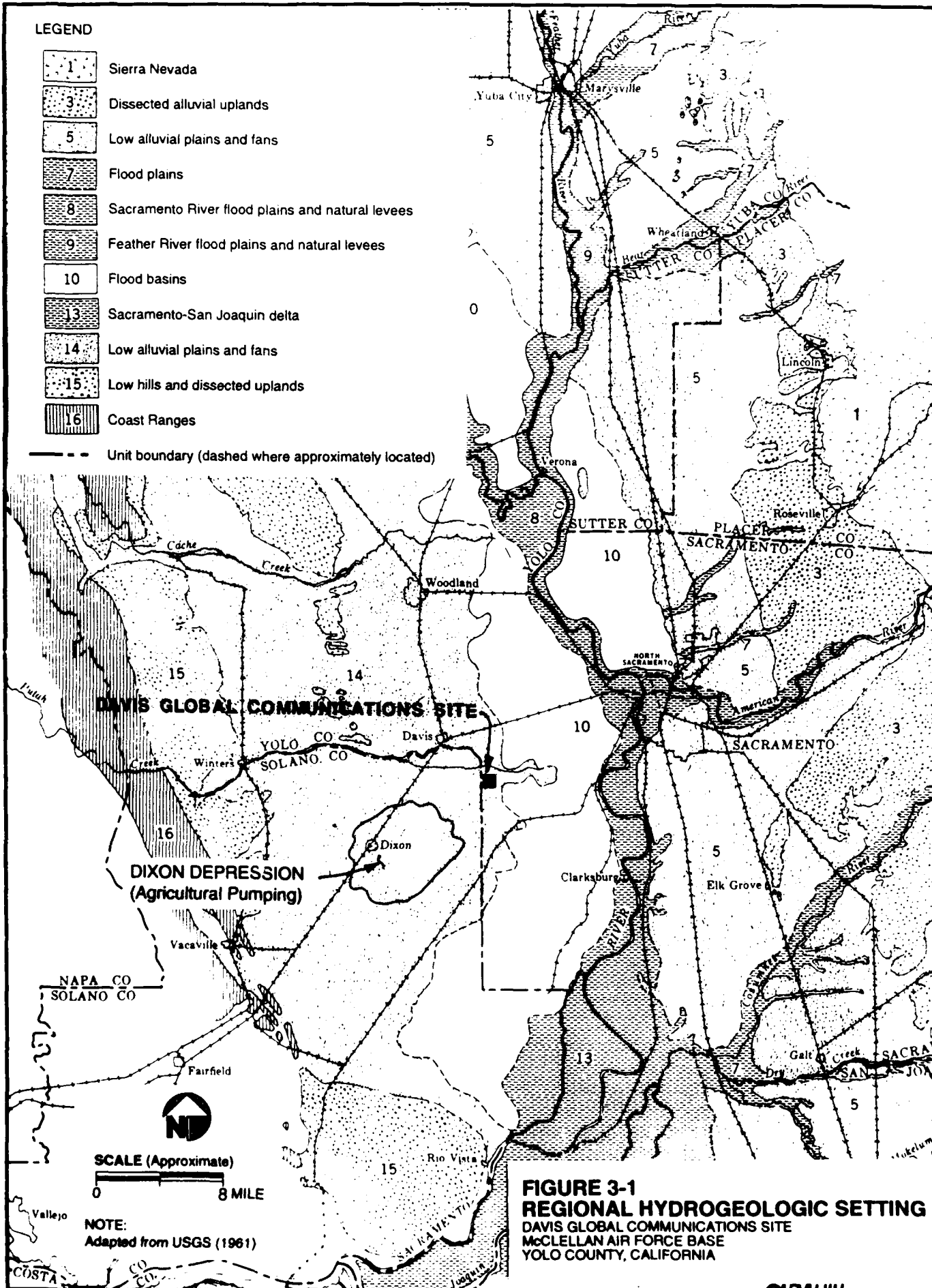
Depth in feet

Aquifer/aquitard boundaries are not clearly defined because of stratigraphic discontinuities across the site.

LEGEND

- 1 Sierra Nevada
- 3 Dissected alluvial uplands
- 5 Low alluvial plains and fans
- 7 Flood plains
- 8 Sacramento River flood plains and natural levees
- 9 Feather River flood plains and natural levees
- 10 Flood basins
- 13 Sacramento-San Joaquin delta
- 14 Low alluvial plains and fans
- 15 Low hills and dissected uplands
- 16 Coast Ranges

--- Unit boundary (dashed where approximately located)



D and E zone coarse-grained deposits are more continuous beneath the site. These formations are more transmissive and are considered regional aquifers in the area.

3.2.2 Vadose or A Zone

Clays comprise most of the vadose zone. The only extensive permeable deposit is a sand deposit typically 10 feet thick found between 20 and 40 feet bgs. It is a fining upward sequence with a coarse sand at the bottom grading upward to a fine sand and silty sand at the top. This deposit is found consistently beneath the fenced compound and east of the fenced compound area, but not west of the fenced compound.

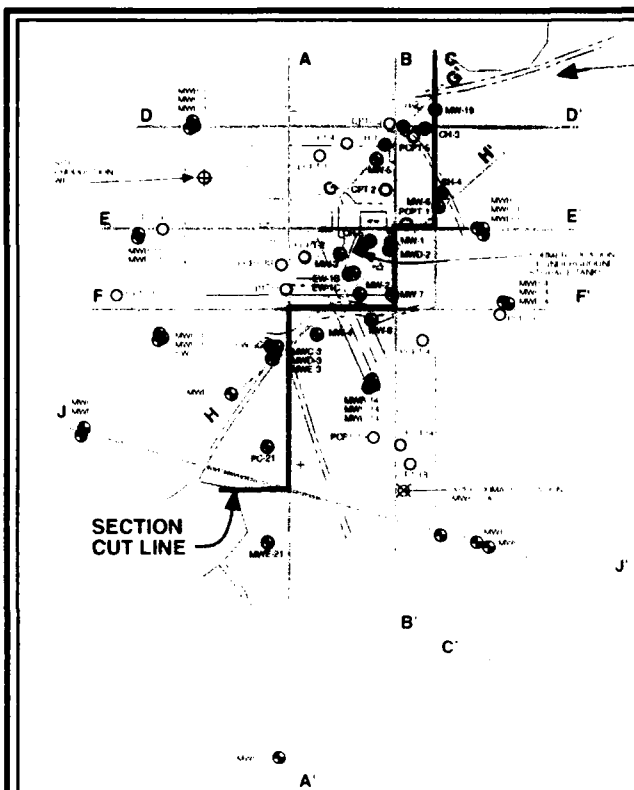
The thickness of the vadose or unsaturated zone ranges from 25 to 70 feet bgs from winter to summer as the water level drops because of regional agricultural pumping. Because the extent of the vadose zone is changing daily because of water level fluctuations, the vadose zone within this document was considered to extend from the ground surface to 40 feet bgs. In a typical year, this zone is unsaturated a majority of the time. The zone between 40 and 70 feet bgs is considered a seasonal vadose zone because it is unsaturated less than half the year. This 40- to 70-foot zone is comprised mainly of fine-grained materials of relatively low permeability and low organic carbon. Contaminants in this region are mobilized each winter as water levels rise, saturating the available pore spaces and dissolving residual contaminants sorbed to the soil. The dissolved contaminants may then flow both laterally and vertically with the groundwater. The predominantly clay soils have a high specific retention of water whereby most of the moisture in the pore spaces is retained after the water table drops. This reduces the available storage within the clays and allows for a large increase in water levels under relatively small amounts of recharge.

3.2.3 B Zone

The B zone extends from 65 feet bgs to approximately 95 feet bgs. In general, permeable deposits are thickest in the area of EW-1B with about 25 feet of well sorted gravel and sand intermixed with silty sand in this vicinity. The permeable deposits thin and pinch out within 100 feet south and west of EW-1B and within 200 to 300 feet north and east from EW-1B (see Figure 3-3 and Chapter 4 cross sections). The permeable materials are bounded above and below by sandy and silty clays. Discontinuous lenses of permeable material are interspersed throughout the subsurface at other locations away from the fenced compound area (near MWB-1, MWB-11, and MWB-14) but little to no contamination has been detected at these locations.

3.2.4 C Zone

In past investigations, the base of the C zone has been defined at approximately 120 feet bgs. Additional field investigation and interpretation has led to interpreting the base of the C zone to be located approximately 145



SITE PLAN

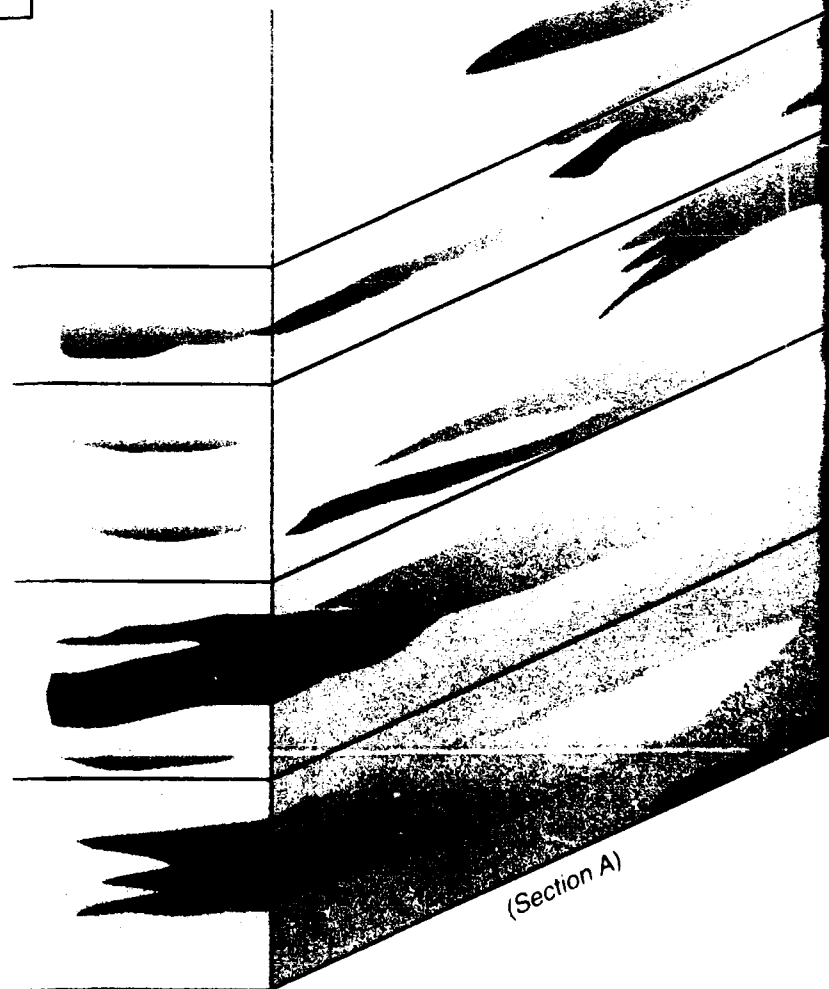
Vadoze
Zone

B
Zone

C
Zone

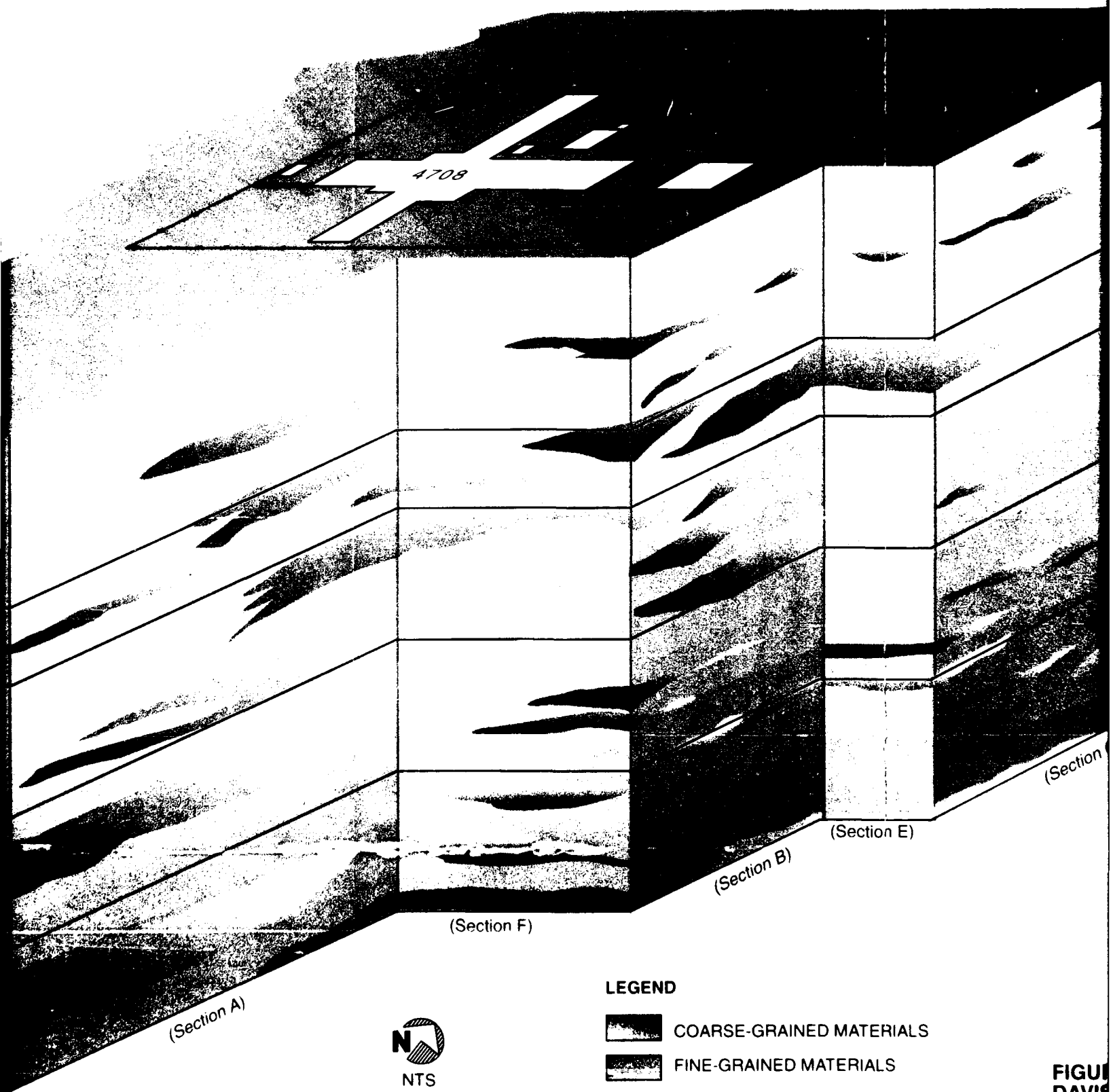
D
Zone

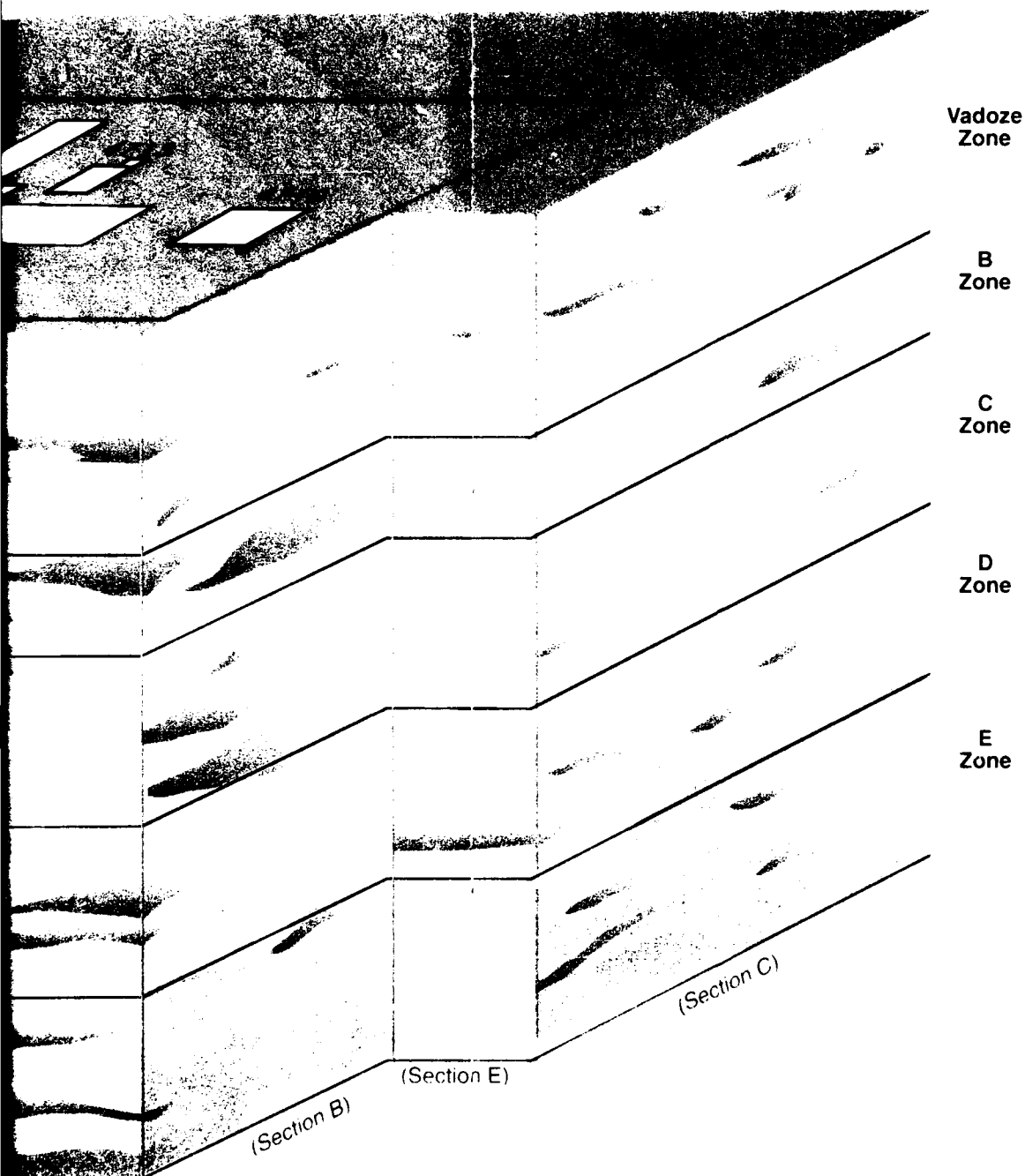
E
Zone



VERTICAL
(Approximate)

Direction
Channel





LEGEND

- COARSE GRAINED MATERIALS
- FINE GRAINED MATERIALS

FIGURE 3-2 DAVIS SITE CONCEPTUAL SITE CROSS SECTION

DAVIS GLOBAL COMMUNICATIONS SITE
MCLELLAN AIR FORCE BASE
YOLO COUNTY, CALIFORNIA

SW

SCALE
1" = 100'

DEPTH
(FT)

0

40

80

120

160

200

240

280

AQUIFER OR AQUITARD	S	K feet/ day	T feet/ day
A-B AQUITARD	NA	NA	NA
B-AQUIFER	1 to 001	3 to 30	100 to 1,000
B-C AQUITARD	NA	NA	NA
C-AQUIFER	7×10^{-5}	25 to 200	1,000 to 3,000
C-D AQUITARD	NA	NA	NA
D-AQUIFER	2×10^{-4} to 1×10^{-5}	100 to 150	1,000 to 3,000
D-E AQUITARD	NA	NA	NA
E-AQUIFER	2×10^{-4} to 1×10^{-5}	100 to 200	3,000 to 7,000
NOTE S = Storage Coefficient K = Hydraulic conductivity T = Transmissivity NA = Not Available			

MWD-10
EI 27

EWC-3
EI 29

MWC-3
MWD-3
MWE-3
EI 27

MW-4
EI 25

FINE-GRAIN

COARSE-GRAIN
MATERIAL

D-10
EI 27

EWC-3
EI 29

MWC-3
MWD-3
MWE-3
EI 27

MW-4
EI 25

EW-1B
EW-1C
EI 29

P-5S
CH-5
P-5D
EI 28.5

MWD-2
EI 28

MW-1
EI 26

MW-6
EI 23

P-4S
CH-4
P-4D
EI 28

FINE-GRAINED MATERIAL

COARSE-GRAINED
MATERIAL

NOTE:
Plan view location
is shown in Figure

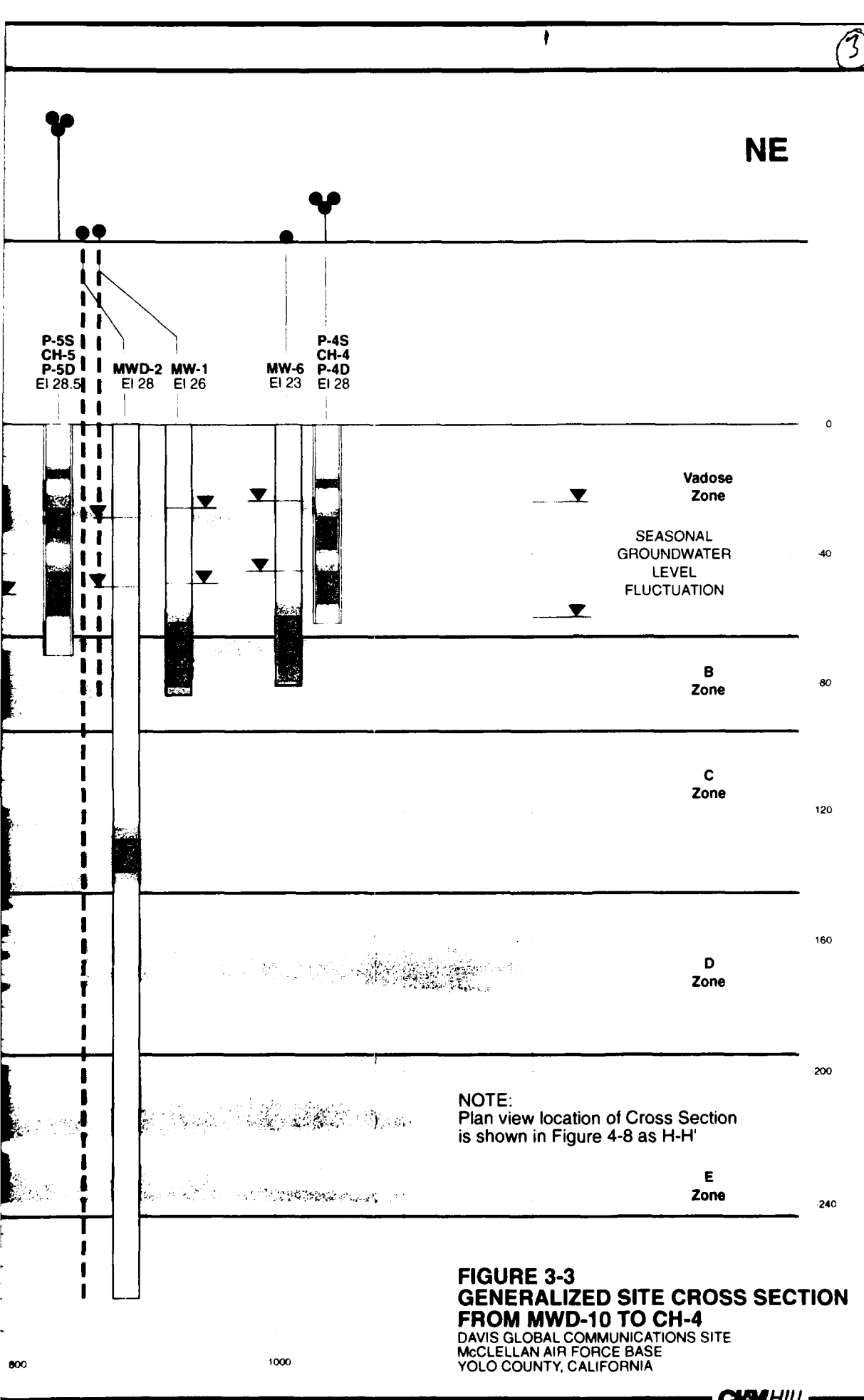
FIGURE 3-3
GENERALIZATIONS
FROM MWD-3
DAVIS GLOBAL CO
McCLELLAN AIR FLD
YOLO COUNTY, CA

400

600

800

1000



feet bgs. In all likelihood, the base of the B zone and the top of the C zone are one depositional sequence. Water levels in the two zones are near equal, and horizontal gradients are very similar.

Extraction Well EW-1C and Monitoring Well MWD-2 are the only wells completed in the C zone within the fenced compound area. The coarse-grained materials within the C zone become more permeable with depth based on well development testing. Most of the permeable units within the C zone above 115 feet bgs are composed of silty sand. The units below 120 feet thicken and are typically composed of sand and gravel with sand. The permeable unit between approximately 120 feet and 145 feet bgs bounded by MWD-2 on the northeast and MWD-10 on the southwest appears to be continuous within this range. This zone has the potential to be a conduit for downward contaminant movement beneath the site by linking the C and D zones near Well Cluster MW3.

3.2.5 D Zone

The D zone extends from approximately 145 to 195 feet bgs. With the exception of the site production well, there are no wells screened within the D zone in the fenced compound area. Most of the permeable material is composed of well-graded gravel and gravel and sand mixtures. A clay matrix separates the permeable units within this zone. The zone appears to be thickest along the entrance road to the compound at depths between approximately 145 to 175 feet. Monitoring Well MWD-13 appears to be screened across the interface of the D and E zones. MWD-13 water levels have been lower than most D zone wells in the past. Near Well Cluster MW3, the lower C zone and upper D zone are separated by less than 10 feet of silt and fine sand. This area has the potential for vertical movement of contamination from above.

The site production well and several offsite agricultural production wells are screened within this zone. Therefore, water levels fluctuate rapidly in response to onsite and offsite pumping. No evidence of this zone was found during drilling of the test hole approximately 2,600 feet north of EW-1B.

3.2.6 E Zone

The E zone extends from approximately 195 feet to 245 feet bgs beneath the site. Currently, only three wells are screened within this zone: MWE-3, MWE-21, and MWE-22. Lean and fat clays separate the layers of poorly sorted gravel and sand within this zone. The permeable unit appears to be about 30 feet thick across the site. This zone is considered a regional aquifer, and most offsite wells in the vicinity of the site are screened across this zone.

3.2.7 Hydraulic Properties

Aquifer hydraulic properties have been estimated based on aquifer testing and testing during well development performed at the site (CH2M HILL, 1992; CH2M HILL 1993). Transmissivities generally increase with depth at the site. Because of the heterogenous nature of the subsurface,

hydraulic properties vary significantly within each aquifer. Table 3-1 gives a range of hydraulic properties estimated for each aquifer. These estimates will be updated as additional data are gathered and interpreted. Aquitard hydraulic properties are more difficult to predict because direct testing on the materials is not performed. Estimates of aquitard vertical resistance are presented in Appendix J, Groundwater Modeling. The hydraulic property estimates were input into the groundwater modeling performed for capture analysis discussed in Appendix J.

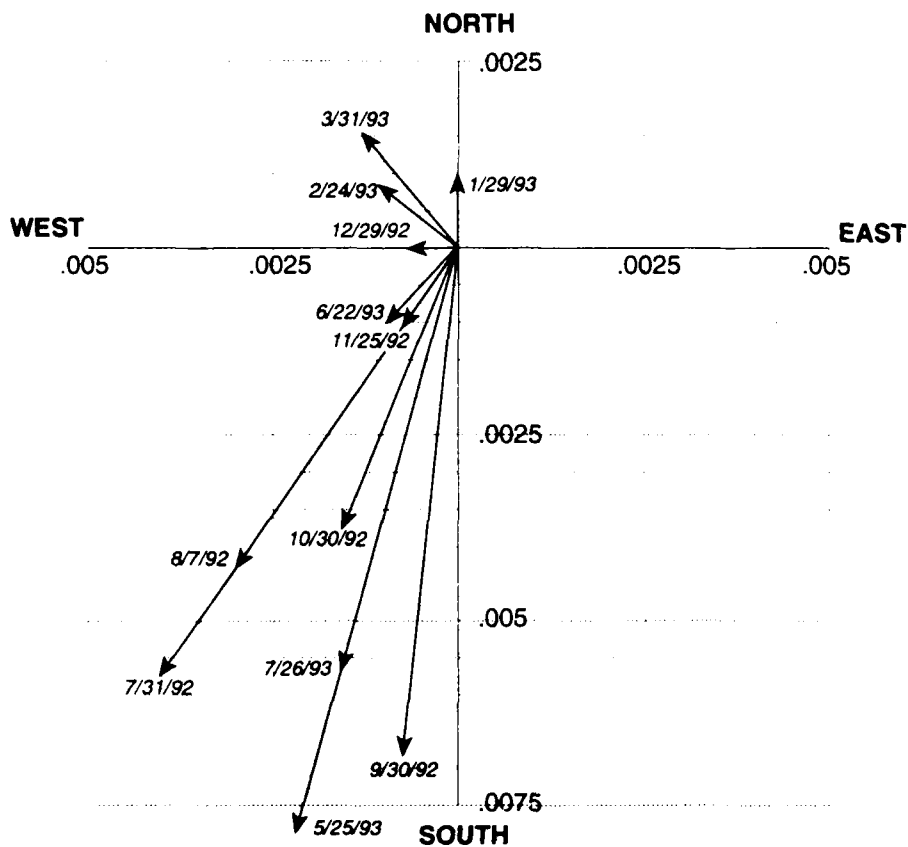
Table 3-1 Estimated Hydraulic Properties			
Aquifer	Storage Coefficient	Hydraulic Conductivity (ft/day)	Transmissivity (ft²/day)
B	0.1 to 0.001	3 to 30	100 to 1,000
C	7×10^{-6}	25 to 200	1,000 to 3,000
D	2×10^{-4} to 1×10^{-5}	100 to 150	1,000 to 3,000
E	2×10^{-4} to 1×10^{-5}	100 to 200	3,000 to 7,000

*Estimated based on D aquifer results.

3.3 Groundwater Levels and Flow Directions

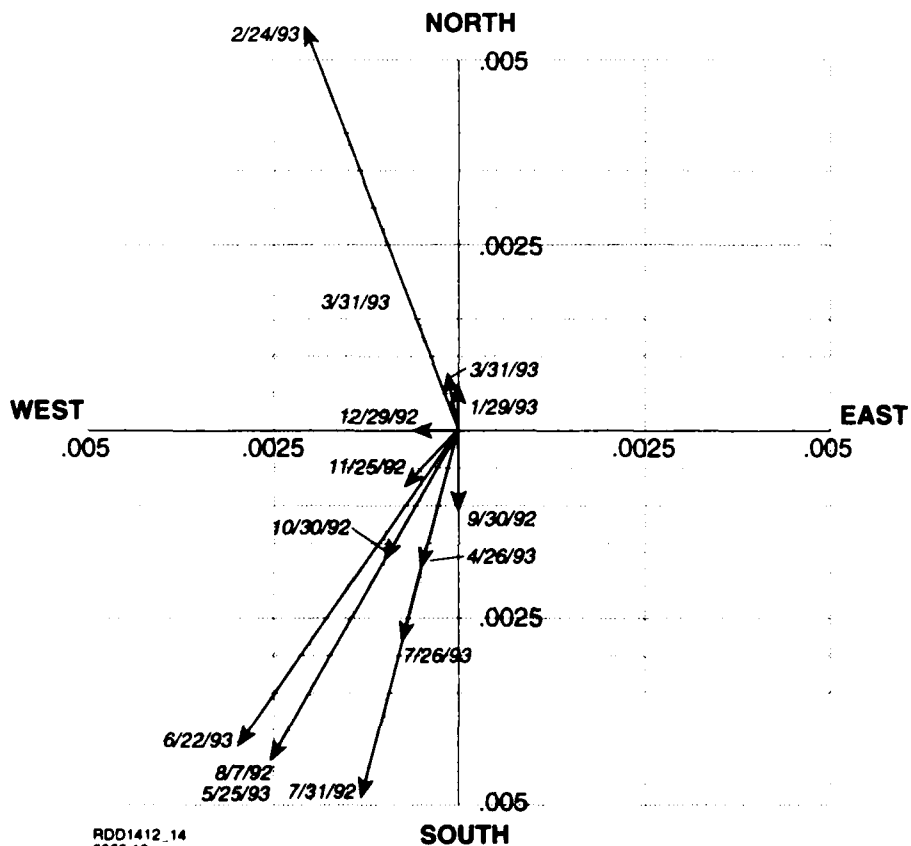
Groundwater levels and flow directions vary greatly beneath the site. A major source of uncertainty with regard to groundwater levels and flow directions remain in the D and E aquifers. Onsite pumping of the site production well and off-site pumping from agricultural wells are operations that influence and dictate groundwater levels and flow directions beneath the site. The pumping schedules cause uncertainty in groundwater flow.

Figures 3-4a, -4b, and -4c are vector diagrams showing the direction and magnitude of the groundwater gradients in the B, C, and D zones between July 1992 and July 1993. Because of the effects of agricultural pumping near the site, groundwater flow directions and flow rates within aquifers beneath the site are variable. Groundwater flows to the south-southeast with a gradient of approximately 0.005 ft/ft in the B and C zones from May to November in response to the regional eastward gradient and the persistent groundwater pumping depression southwest of the site near the City of Dixon. Groundwater flows north-northwest in the winter in the B and C zones with a gradient of approximately 0.0008. The D zone gradient is nearly flat most of the year. On March 31, 1993, the D zone gradient tended slightly to the southwest. On May 25, 1993, the D zone gradient was towards the east, probably in response to pumping from three agricultural wells located one-quarter to one-half mile east of the compound. Later in the summer pumping season and in the fall, the gradient was too shallow to confidently measure. Water level contour maps are presented in Appendix E, Groundwater Contour Maps.

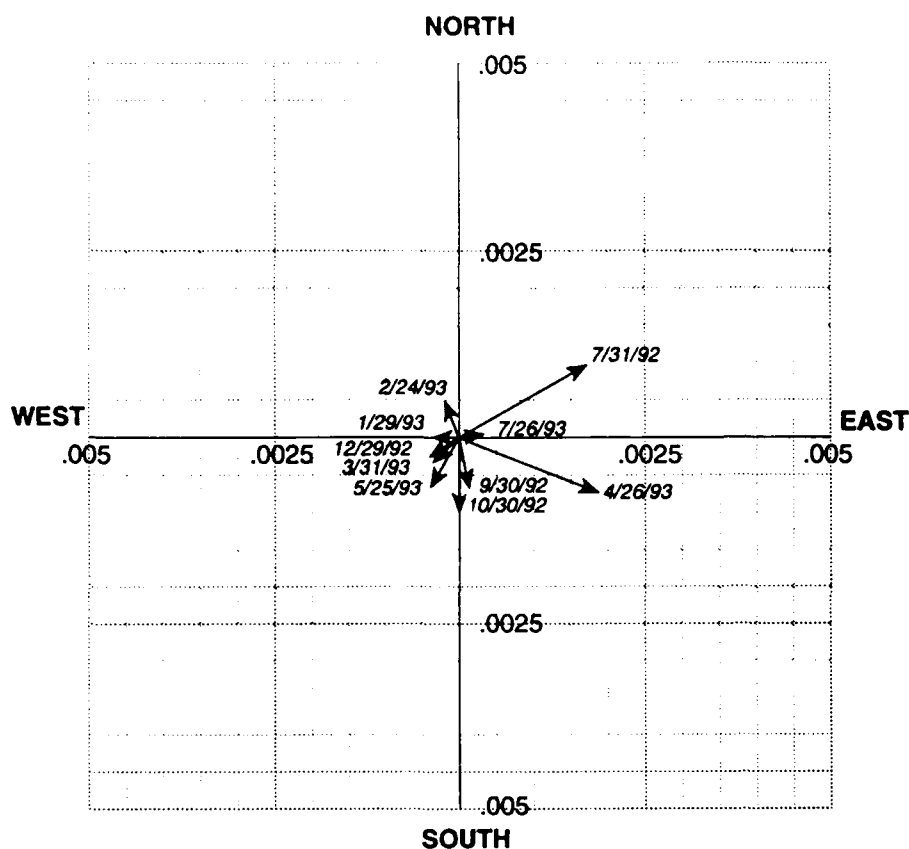


NOTE: The gradient on 4/26/93 was flat and is not presented in the figure.

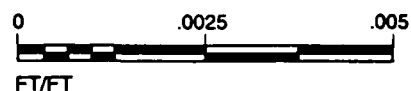
**FIGURE 3-4a
B AQUIFER HORIZONTAL
GRADIENTS JULY 1992
THROUGH JULY 1993**



**FIGURE 3-4b
C AQUIFER HORIZONTAL
GRADIENTS JULY 1992
THROUGH JULY 1993**



NOTE: The gradient on 8/7/92, 11/25/92, and 6/22/93 was flat and are not presented in the figure.

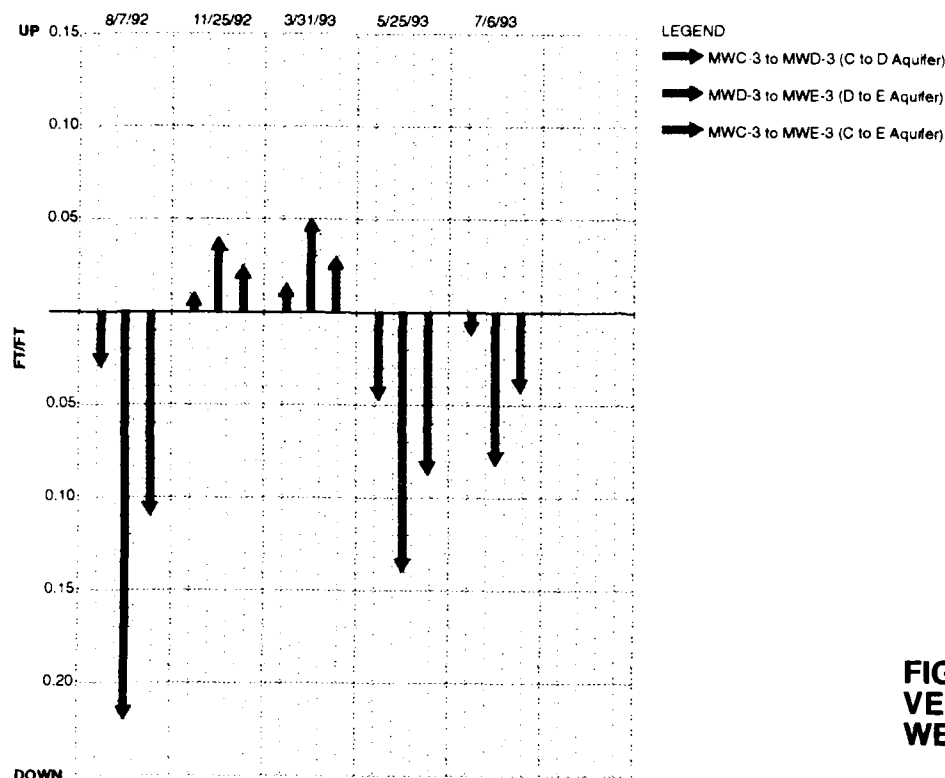


**FIGURE 3-4c
D AQUIFER HORIZONTAL
GRADIENTS JULY 1992
THROUGH JULY 1993**

The horizontal gradients measured in the B, C, and D aquifers between July 1992 and July 1993 are generally consistent with those measured during 1990 and 1991. Groundwater flow directions within each aquifer varied according to the season. During 1991, groundwater levels within the B and C aquifers were nearly the same. Groundwater flowed to the west-southwest during the winter and to the south during the spring and summer. D aquifer groundwater flowed to the west during the winter and to the east-southeast during the summer.

Figure 3-5 shows vertical gradients between the C and D zones, C and E zones, and D and E zones based on measurements at Well Cluster MW3 south of the compound. Downward gradients exist from May to October because of agricultural pumping from deep zones. Gradients from the D to E zones are the largest at 0.22 ft/ft downward during summertime pumping conditions because the E zone is pumped heavily for agriculture. These downward gradients cause flow from shallow zones to deeper zones at the site. Slight upward gradients exist for all zones from November through March preventing downward contaminant movement.

Vertical gradients for other well clusters at the site were calculated for the same time period and are presented in Attachment 2 to the Response to Comments section of this report. The vertical gradient trends are generally consistent across the site.



**FIGURE 3-5
VERTICAL GRADIENTS AT
WELL CLUSTER MW3**

Groundwater levels were recorded hourly at Well Cluster MW1 with a data logger from July 1992 to July 1993. The annual fluctuation in groundwater levels from the B, C, and D aquifer zones are presented in Figure 3-6. The upward vertical gradient from the D aquifer to the B and C aquifers is shown on the figure and occurred from mid-September 1992 through mid-April 1993. Groundwater levels were exceptionally low in the summer of 1992 because of a 7-year drought and increased groundwater pumping in the site vicinity. Levels recovered to just above sea level in the winter because precipitation was 75 percent above average. MWB-1 and MWC-1 responded almost identically measuring within several hundredths of a foot of each other. MWD-1 groundwater levels were several feet below MWC-1 during agricultural pumping because of downward gradients induced by pumping from deep agricultural wells.

Groundwater levels in MWD-1 were above MWC-1 during the winter groundwater recharge period.

3.4 Vadose Zone/Saturated Zone Interface

The vadose zone plays a key role in understanding the subsurface conditions at the Davis Site. The following vadose zone factors have the greatest influence in understanding subsurface complexities:

- Cyclic annual movement of groundwater levels by 30 to 50 feet
- Likely source of historic contamination
- Fine-grained materials dominate the profile

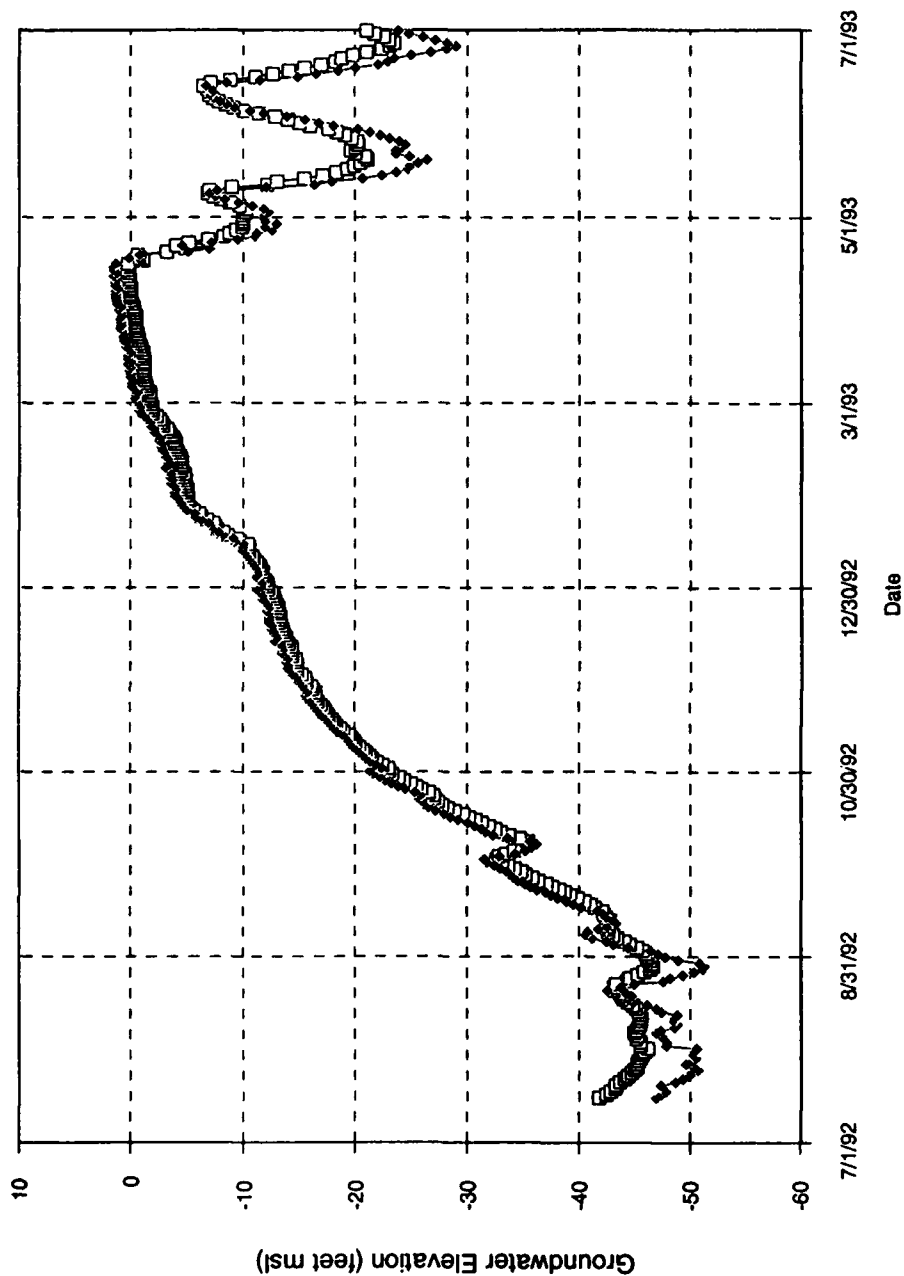


FIGURE 3-6
GROUNDWATER ELEVATIONS
AT WELLS MWB-1, MWC-1, MWD-1
JULY 16, 1992 TO JULY 1, 1993
 DAVIS GLOBAL COMMUNICATIONS SITE
 McCLELLAN AIR FORCE BASE
 YOLO COUNTY, CALIFORNIA

Figure 3-7 shows a schematic of the vadose zone saturated zone interface. The potential contaminant fate and transport between these zones will be discussed in the next chapter. The annual fall of groundwater levels creates a seasonal vadose zone, which is desaturated during summer pumping conditions. Pressures below and above atmospheric pressure have been measured within this seasonal vadose zone probably caused by the rapid displacement of water with air as water levels fall and the rapid displacement of air with water as water levels rise. Because the vadose zone is a source of contamination, expected degradation values can be compared to measured values to help understand the subsurface conditions.

GROUNDWATER MONITORING WELL

GROUND SURFACE

25 TO 35 FEET

GROUNDWATER

WINTER
CONDITION

GROUNDWATER MONITORING WELL

GROUND SURFACE

60 TO 70 FEET

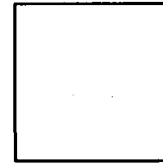
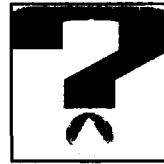
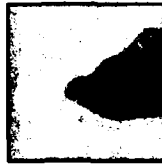
GROUNDWATER

SUMMER
CONDITION

**FIGURE 3-7
SCHEMATIC OF VADOSE ZONE/
SATURATED ZONE INTERFACE**

DAVIS GLOBAL COMMUNICATIONS SITE
McCLELLAN AIR FORCE BASE
YOLO COUNTY, CALIFORNIA

CHM HILL



Chapter 4 Nature and Extent of Contamination

Data generated during the Remedial Investigation (RI) fieldwork are used in this chapter to estimate the mass and distribution of contamination in the vadose zone and groundwater. The data on contaminant mass and distribution are combined with our current understanding of the hydrogeology as presented in Chapter 3 to develop a working hypothesis on the mechanisms of transport that control contaminant movement at the Davis Site. The evaluation presented in this chapter will be used to develop feasibility study (FS) alternatives and eventually lead to a remedial action plan.

4.1 Extent of Contamination

4.1.1 Discussion of Contaminants of Concern

Contaminants of Concern (COCs) were chosen for the groundwater and soil gas on the basis of recent and historical sampling results. Chapter 1 discusses the selection of COCs. A subset of the full COC list (SCOCs) is presented in this chapter for contaminant fate and transport considerations. The subset consists of the compounds from Table 1-1 that are present above groundwater MCLs or that represent greater than 1 percent of the mass of contamination within the vadose zone outside of the area of influence from the bioventing study. The SCOC list is shown in the margin. Tables 4-1 and 4-2 present summary statistics for the groundwater and vadose zone SCOCs. Contaminant data are presented in Appendix U. The detected SCOCs in groundwater and soil gas are presented on cross-sections located at the end of this chapter.

SCOCs	
Vadose Zone	Groundwater
PCE	PCE
TCE	TCE
1,1-DCE	1,1-DCE
Benzene	Benzene
Vinyl Chloride	Vinyl Chloride
Toluene	1,1-DCA
Xylene	1,2-DCE

Table 4-1
Summary Statistics for Groundwater SCOCs

Compound	Number of Detects/ Samples	Frequency of Detects	Range of Detects (µg/l)	Mean	Standard Deviation
PCE	151/312	0.48	0.12 to 1,400	95.97	214.46
TCE	214/295	0.73	0.27 to 3,000	104.47	278.10
1,1-DCE	113/330	0.34	<0.0 to 390	26.36	44.21
Benzene	24/310	0.08	<0.0 to 11	1.71	2.56
Vinyl Chloride	30/340	0.09	<0.0 to 410	111.43	129.84
1,1-DCA	40/340	0.12	<0.0 to 38	5.06	8.56
cis-1,2-DCE	64/223	0.29	0.41 to 870	14.53	74.31
trans-1,2-DCE	35/120	0.29	<0.0 to 3,400	409.45	922.92

Table 4-2
Summary Statistics for Vadose Zone SCOCs

Compound	Number of Detects/ Samples	Frequency of Detects	Range of Detects (µg/l)	Mean	Standard Deviation	Percent of Total Mass
PCE	85/92	0.92	0.020 to 541.20	44.87	99.43	90.1
TCE	52/92	0.57	0.010 to 50.35	3.96	8.94	4.2
1,1-DCE	32/92	0.35	0.030 to 10.14	1.86	2.69	0.3
Benzene	36/92	0.39	0.007 to 1.12	0.11	0.19	0.1
Vinyl Chloride	1/92	0.01	<0.0 to 0.0030	0.00	--	2.0
Toluene	59/92	0.64	0.007 to 25.90	1.11	4.51	0.7
m-, p-Xylene ^a	43/92	0.47	0.004 to 16.30	0.50	2.47	2.6
o-Xylene ^b	25/92	0.27	0.013 to 17.50	0.83	3.47	0.0

^aSum of isomers.
^b1,2-Dimethylbenzene.

Although not included with the groundwater SCOCs, ethylene dibromide (EDB) and trihalomethanes (THMs) have been detected in samples from the site production well. EDB was used heavily in the agricultural industry as a soil fumigant until the early 1980s. EDB has been detected at levels over one hundred times greater than the maximum contaminant level (MCL) of 0.02 µg/l. EDB analysis has not been included in monitoring well sampling and analysis to date. Therefore, no additional data exist from site monitoring wells. The site production well is screened within the C and D aquifers and future sampling for EDB in monitoring wells is recommended.

It is suspected that the occurrence of THMs in the site production well samples is a result of sampling the water downstream of the chlorination point. Samples from upstream and downstream of the point of chlorination should be collected during the next site production well sampling event. It is suspected that the results will show that THMs will be detected in the downstream sample only.

4.1.2 Hydrocarbon Contamination

A known source of petroleum hydrocarbon contamination at the site is from the leaking underground fuel storage tanks that were removed during 1988. The soil is contaminated beneath the former tank locations down to a depth of approximately 65 feet below ground surface (bgs). Petroleum hydrocarbon related compounds (benzene, toluene, ethylbenzene, and xylene) have been detected in the soil gas and in groundwater samples.

Total petroleum hydrocarbon contamination was detected in soil samples from 30 to 65 feet bgs during drilling of Well CH-5 in November 1992. The soil contamination is mainly found at two subsurface locations. The first location is at the interface of a silty sand layer and a clay layer at a

depth of 30 to 40 feet bgs (see Appendix K, Hydrocarbon Remediation Options). This depth represents approximate mean annual high groundwater level. The petroleum hydrocarbons typically float on the groundwater surface, and this depth may represent a layer of deposition for the hydrocarbons in soil because of the groundwater levels and because of the change in lithology from a more coarse-grained to a more fine-grained matrix.

The other zone of contamination occurs around 60 feet bgs in a clayey matrix. This depth is the approximate depth of low annual groundwater and may represent a concentration of the contamination because of the contamination floating on the groundwater table.

4.2 Development of Contaminant Mass Estimates

4.2.1 Selection of Target Areas and Target Volumes

Target areas were developed by interpreting existing and historic contamination data. The extent of contamination within each zone is a major source of uncertainty. It is possible that monitoring wells do not indicate the full extent of contamination. Uncertainty may increase because of contaminant transport and spreading. A discussion of how uncertainty affects target zones is presented in Chapter 6.

To evaluate capture scenarios for vadose zone and groundwater contamination, target areas must be selected. Target areas for each aquifer were selected on the basis of the historical water quality results with an emphasis on the February and July 1993 results for each medium of concern. The target areas approximately encompass the area in which contamination has been detected. However, it is possible that undetected contamination may exist beyond the target area.

Once target areas have been selected, target volumes can be calculated. Target volumes represent the target area multiplied by the thickness of each respective zone. Target volumes do not account for porosity. Unit target volumes can be defined as the volume of air or water that is contained within each respective target volume. A unit target volume represents a single pore air or pore water exchange. More than a unit target volume of extraction is needed to adequately remediate a selected contaminated medium. For the saturated zone, the extracted volume is typically five to ten times the unit target volume. For the vadose zone, the extracted volume is typically hundreds or thousands times the unit target volume. The actual number of pore air or pore water exchanges required will depend in part on the performance of the extraction system. Therefore, only unit target volumes are presented for this report.

To estimate the unit target volumes for each zone, the respective target area is multiplied by the porosity of the medium and then multiplied by the thickness of the medium. The target areas and unit target volumes are presented in Table 4-3.

Table 4-3 Target Areas and Unit Target Volumes				
Zone	Target Area (ft²)	Target Area Thickness (ft)	Porosity	Unit Target Volume (gal.)
Vadose Zone	131,200	40	0.40	2,100,000 *
A-B Aquitard	453,000	25	0.45	38,100,000
B Aquifer	453,000	30	0.40	40,700,000
B-C Aquitard	649,350	20	0.45	43,700,000
C Aquifer	649,350	30	0.39	56,800,000
C-D Aquitard	969,000	20	0.45	65,200,000
D Aquifer	969,000	30	0.35	76,100,000
D-E Aquitard	950,000	20	0.45	63,900,000
E Aquifer	950,000	30	0.35	74,600,000
*Vadose zone unit target volume units of ft ³ .				

Figure 4-1 is a base map for Overlay Figures 4-1a through 4-1d. The target areas for the B, C, D, and E aquifers are given in Figures 4-1a through 4-1d. The E aquifer target area is based on water quality results from MWE-3, MWE-21, and MWE-22. Sampling results from the E aquifer monitoring wells indicate that volatile organic compound (VOC) concentrations are below the allowable MCL. In samples from aquifers B, C, and D, VOC concentrations are above MCLs. Contaminant concentrations near or at the boundary of the target areas are presented on the overlays. Typically, the plotted contaminant values have been detected at irregular intervals over the past 4 to 5 years. Some of the values may be representative of seasonal changes in groundwater quality.

Figure 4-2 is a base map for Overlay Figure 4-2a. Soil gas sampling locations are shown in Figure 4-2a. Polygon areas are shown in Figure 4-2b. Sampling results for the 5-foot, 10-foot, 20-foot, and 30-foot depths are shown in Figures 4-2c through 4-2f. The soil gas target areas were delineated based on shallow soil gas sampling results and soil vapor monitoring well (SVMW) sampling results. The target areas approximately encompass the areas where soil gas contamination has been detected. Soil gas sampling was conducted to a depth of approximately 40 feet bgs. Therefore, the base of the vadose zone was assumed to extend to a depth of 40 feet bgs. The seasonally saturated zone between 40 feet and 70 feet bgs was accounted for during the mass estimate for groundwater as the A-B aquitard.

4.2.2 Mass of Contamination

Mass estimates for the SCOCs within each zone were prepared based on the target areas presented in Figures 4-1 and 4-2. Mass estimates for the vadose zone were based on shallow soil gas results and SVMW and

piezometer sampling performed during 1992. Groundwater contamination estimates were based on water quality results from the February and July 1993 groundwater sampling.

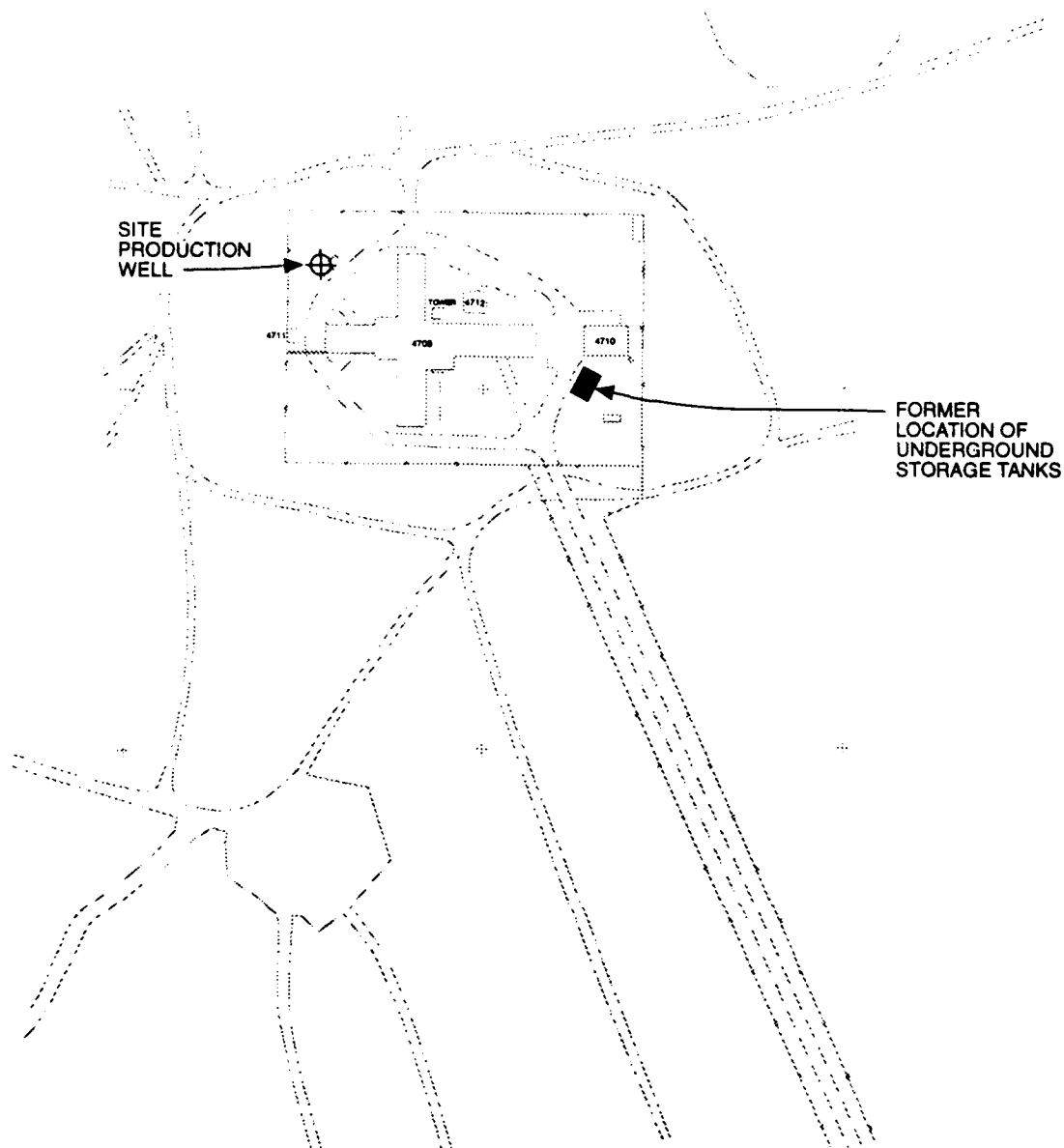
4.2.2.1 Vadose Zone

The SCOCs in the vadose zone were chosen by determining which compounds comprised over 1 percent of the total contaminant mass in the vadose zone. The vadose zone contaminant mass exists in three forms: sorbed onto the soil matrix, dissolved in pore water, and present in soil gas. Soil gas results were input into partitioning equations to estimate the total contaminant mass at equilibrium. All three forms were considered in calculations performed to estimate the total mass of contamination present. A complete discussion of the approach used for the vadose zone contaminant mass estimation is given in Appendix F(b), Mass Estimate for Vadose Zone Contamination. A more rigorous discussion of the equilibrium partitioning between vapor, liquid, and adsorbed phases can be found in W. A. Jury, W. F. Spencer, and W. J. Farmer (1983).

To estimate the contaminant mass present, the vadose zone target area was subdivided into 11 polygons of known area (see Appendix F(b), Figure F(b)-1). Each polygon was subdivided vertically into four depth zones. Contaminant concentrations within each depth zone were estimated based on measured levels at specific points within each polygon. The size of the polygons increased with decreasing contaminant concentrations. Soil gas concentrations were converted into total soil concentrations using equilibrium partitioning equations (HydroGeoChem, Inc., 1989). The total estimated mass of contamination present in the vadose zone is 45 kg (98 lb) as indicated in Table 4-4 on page 4-25. This is approximately 14 percent of the total mass of known contamination at the site. Tetrachloroethene (PCE) accounts for over 90 percent of the vadose zone mass.

4.2.2.2 Groundwater

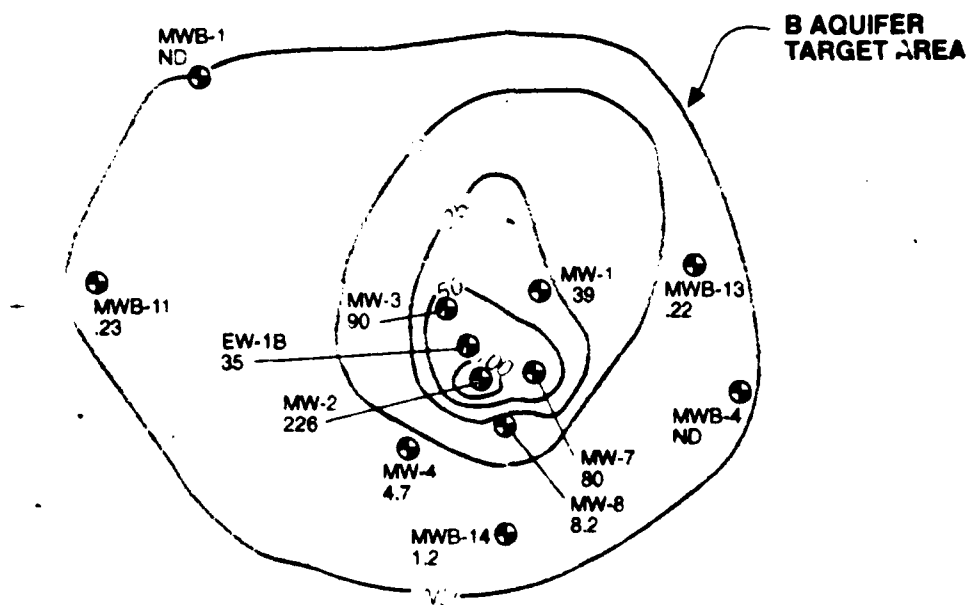
The SCOCs for the groundwater were chosen based on historical groundwater quality data collected from site monitoring wells since 1988. Detected contaminants with the greatest frequency of results above MCLs were chosen as SCOCs. February and July 1993 sampling results were chosen as a basis for estimation of contaminant mass within each aquifer and aquitard. A detailed discussion of the mass estimation is presented in Appendix F(a), Mass Estimate for Groundwater Contamination.



SCALE (Approximate)

0 250 FEET

FIGURE 4-1
SITE BASE MAP
DAVIS GLOBAL COMMUNICATIONS SITE
MCLELLAN AIR FORCE BASE
YOLO COUNTY, CALIFORNIA

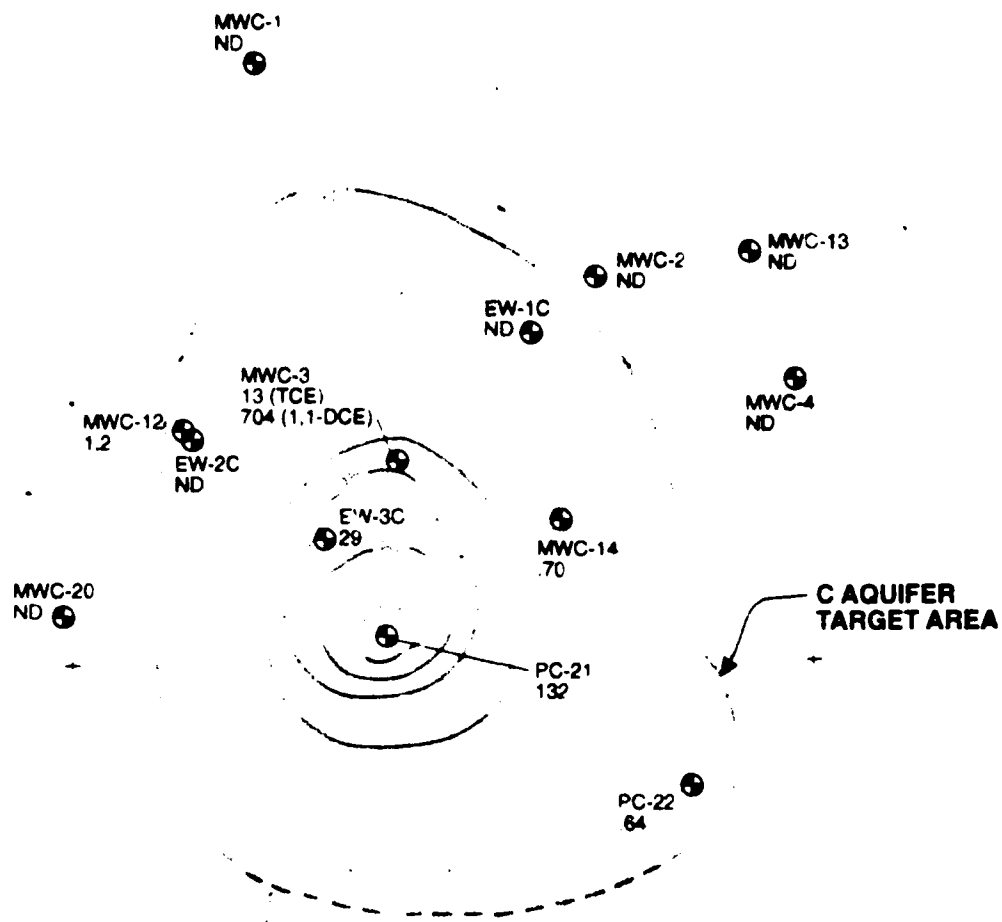


LEGEND

● GROUNDWATER MONITORING WELL

— B AQUIFER TCE CONCENTRATIONS ($\mu\text{g/l}$), 7/93

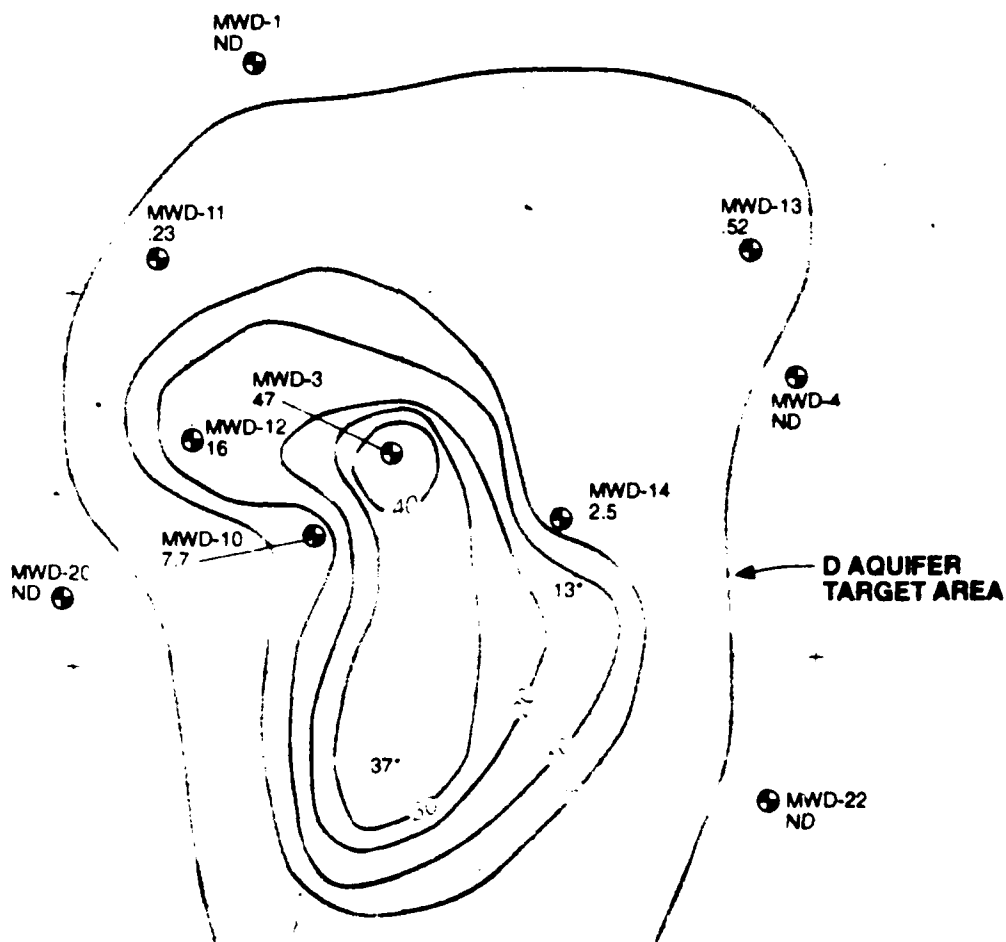
FIGURE 4-1a
B AQUIFER TARGET AREA
 DAVIS GLOBAL COMMUNICATIONS SITE
 McCLELLAN AIR FORCE BASE
 YOLO COUNTY, CALIFORNIA



LEGEND

- ⊕ GROUNDWATER MONITORING WELL
- C AQUIFER TCE CONCENTRATIONS (μg/l), 7/93

FIGURE 4-1b
C AQUIFER TARGET AREA
 DAVIS GLOBAL COMMUNICATIONS SIT
 McCLELLAN AIR FORCE BASE
 YOLO COUNTY, CALIFORNIA



LEGEND



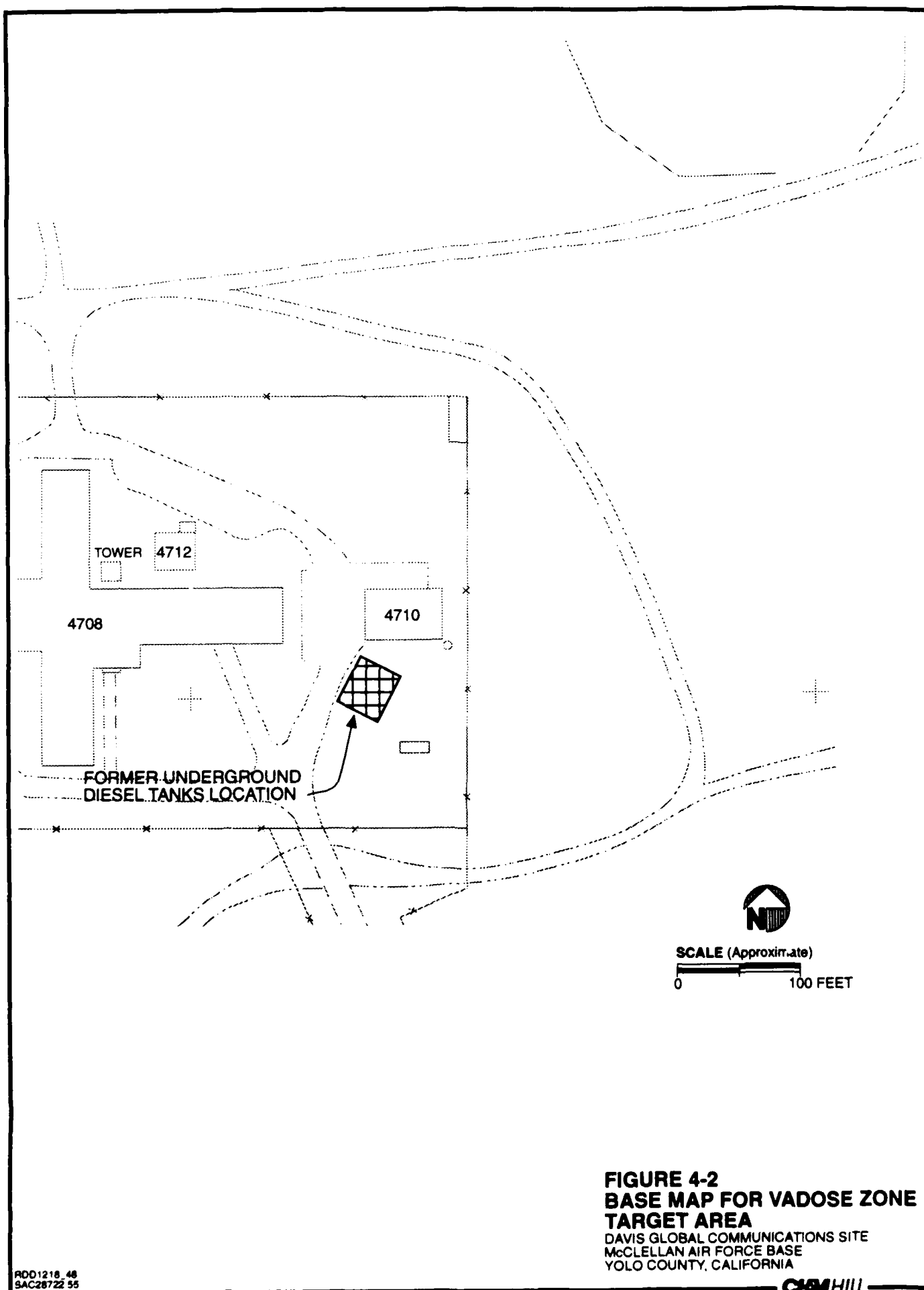
GROUNDWATER MONITORING WELL

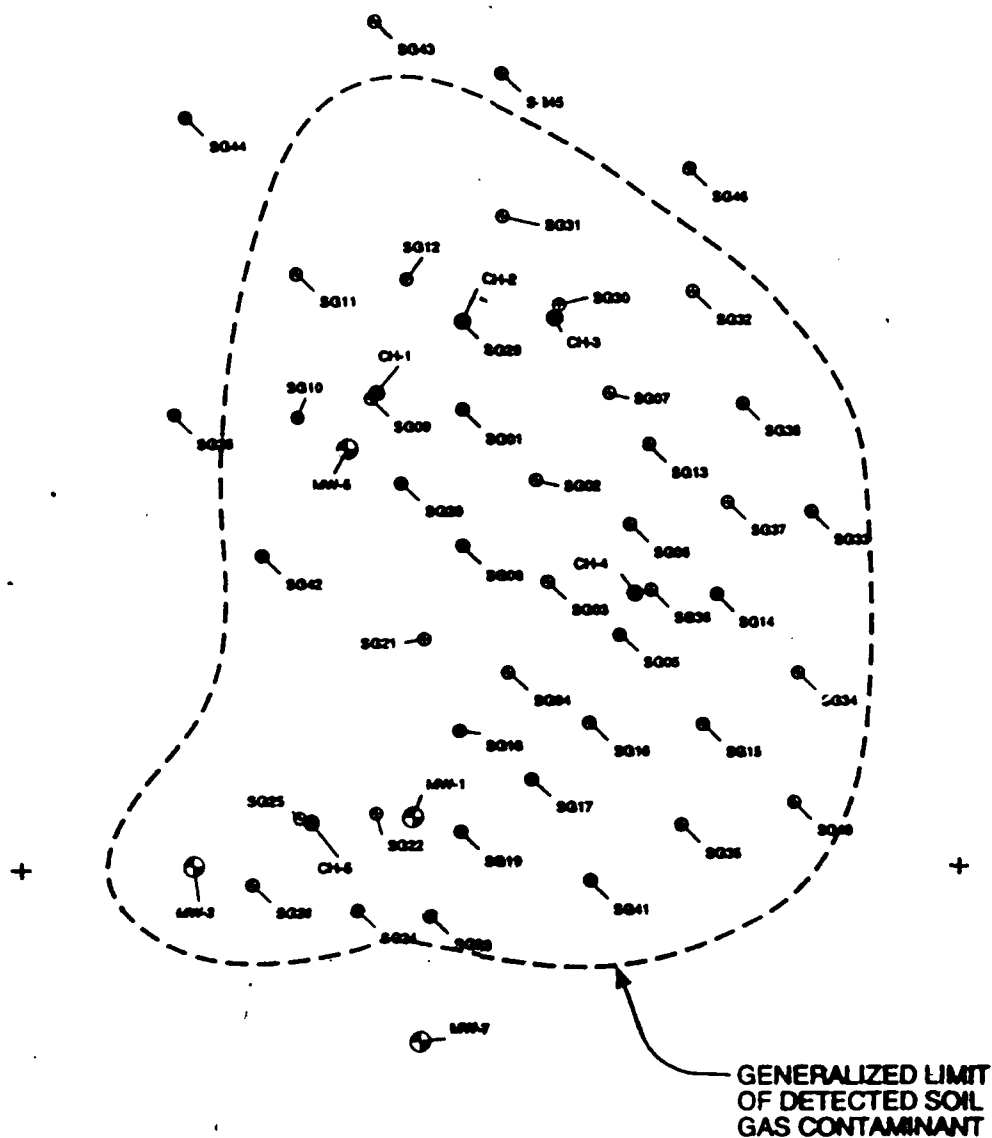


D AQUIFER TCE CONCENTRATIONS ($\mu\text{g/l}$), 7/93

* SAMPLES TAKEN DURING DRILLING

FIGURE 4-1c
D AQUIFER TARGET AREA
 DAVIS GLOBAL COMMUNICATIONS SITE
 MCCLELLAN AIR FORCE BASE
 YOLO COUNTY, CALIFORNIA

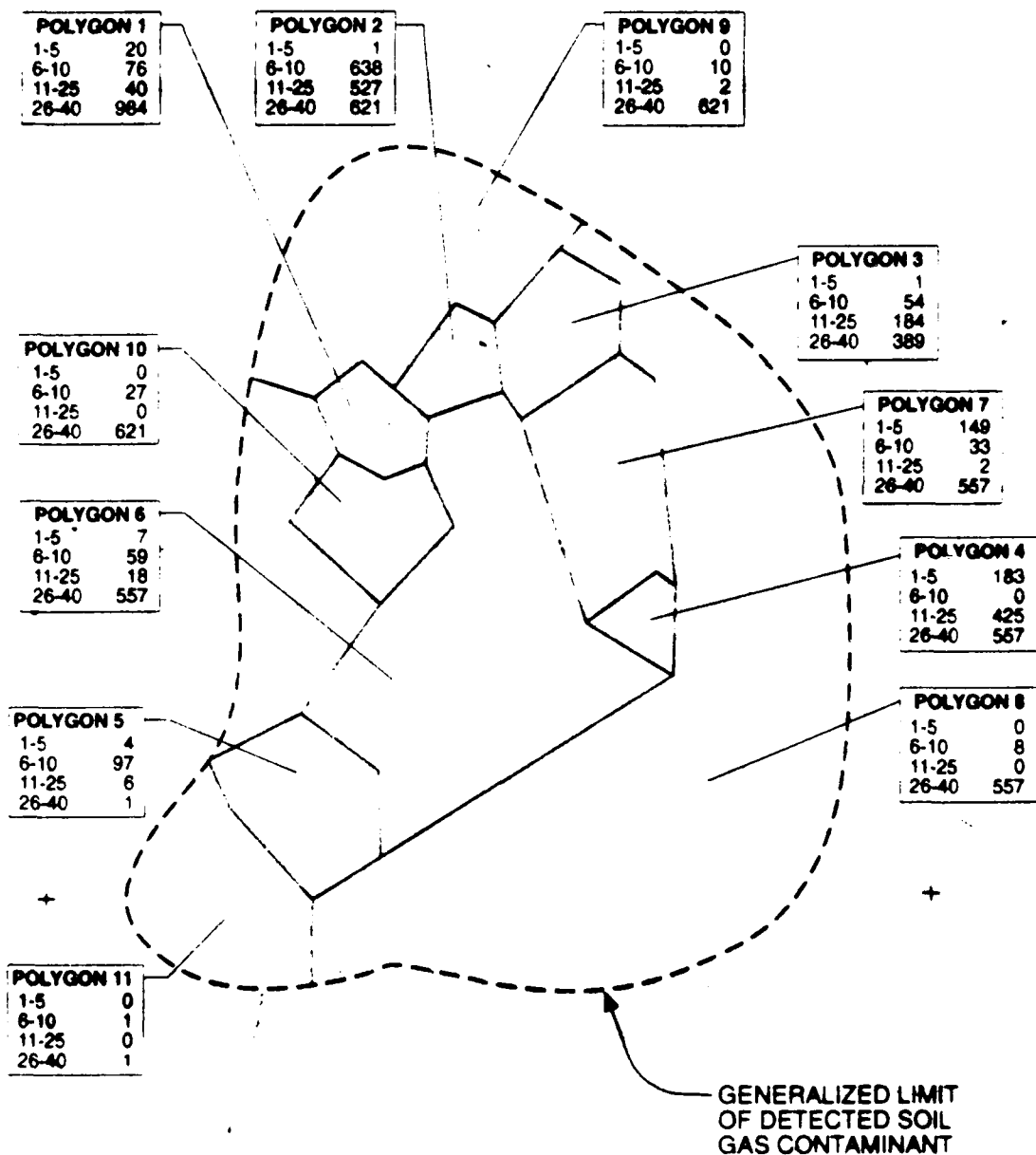




LEGEND

- SOIL GAS SAMPLE LOCATIONS
- ⊕ GROUNDWATER MONITORING WELL
- SOIL VAPOR MONITORING WELL

FIGURE 4-2a
VADOSE ZONE TARGET AREA
 DAVIS GLOBAL COMMUNICATIONS SITE
 MCCLELLAN AIR FORCE BASE
 YOLO COUNTY, CALIFORNIA



LEGEND

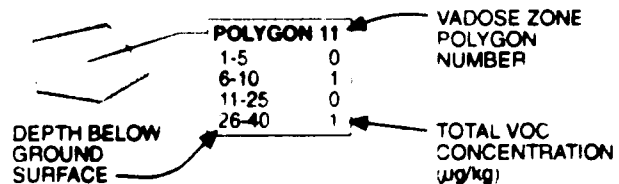
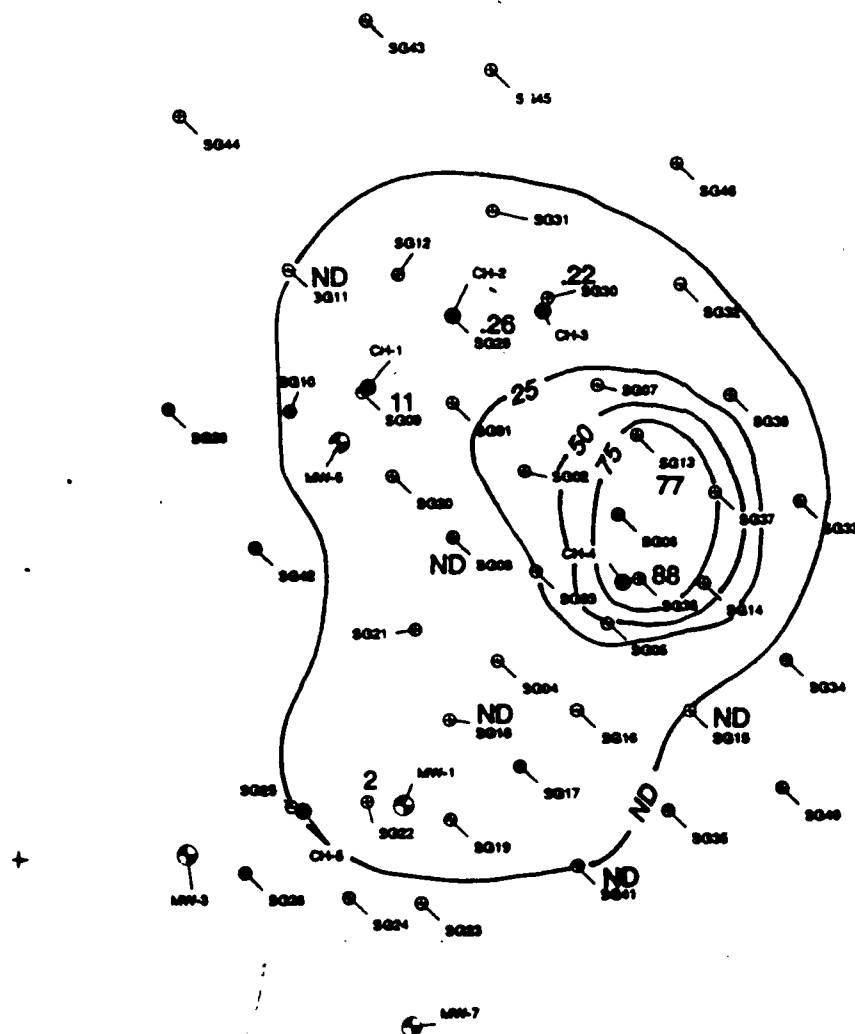


FIGURE 4-2b
POLYGON AREAS AND VADOSE
ZONE CONTAMINANT
CONCENTRATION ESTIMATES
 DAVIS GLOBAL COMMUNICATIONS SITE
 McCLELLAN AIR FORCE BASE
 YOLO COUNTY, CALIFORNIA

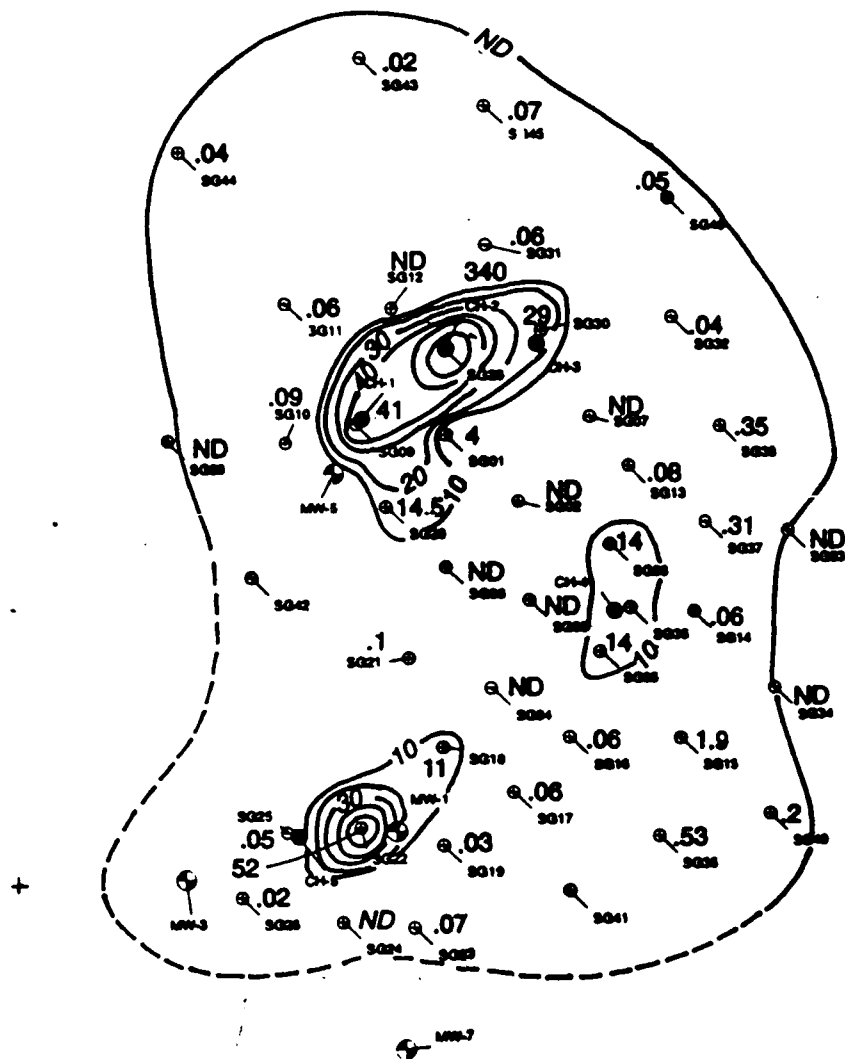
SOURCE: CH2M HILL VOC Mass Estimate - Appendix F



LEGEND

- SOIL GAS SAMPLE LOCATIONS
- ⊕ GROUNDWATER MONITORING WELL
- SOIL VAPOR MONITORING WELL
- 2 SAMPLE RESULTS FROM SHALLOW SOIL GAS SURVEY 9/15/92-10/8/92
- ND NON DETECT

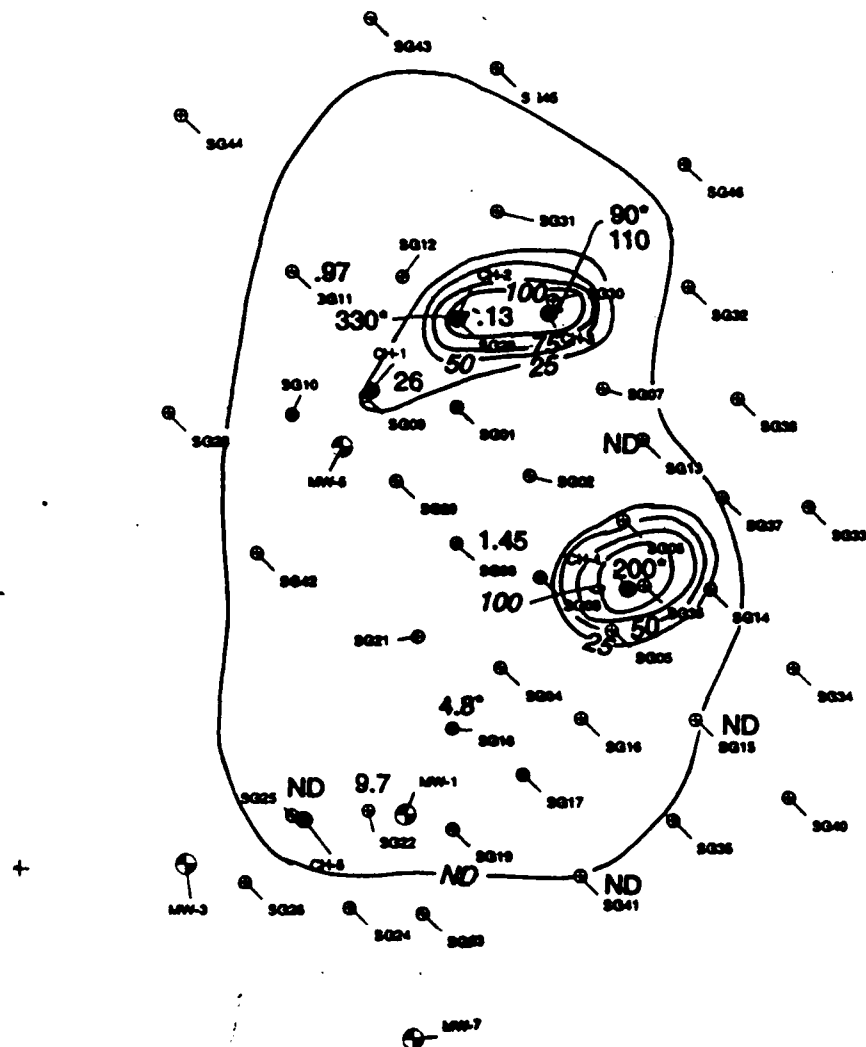
FIGURE 4-2c
VADOSE ZONE PCE CONCENTRATIONS
FROM 5 FEET BGS
 DAVIS GLOBAL COMMUNICATIONS SITE
 MCCLELLAN AIR FORCE BASE
 YOLO COUNTY, CALIFORNIA



LEGEND

- SOIL GAS SAMPLE LOCATIONS
- ⊕ GROUNDWATER MONITORING WELL
- SOIL VAPOR MONITORING WELL
- 2 SAMPLE RESULTS FROM SHALLOW SOIL GAS SURVEY 9/15/92-10/6/92
- ND NON DETECT

FIGURE 4-2d
VADOSE ZONE PCE CONCENTRATIONS
FROM 10 FEET BGS
 DAVIS GLOBAL COMMUNICATIONS SITE
 MCCLELLAN AIR FORCE BASE
 YOLO COUNTY, CALIFORNIA



LEGEND

- SOIL GAS SAMPLE LOCATIONS
- ⊕ GROUNDWATER MONITORING WELL
- SOIL VAPOR MONITORING WELL
- 2 SAMPLE RESULTS FROM SHALLOW SOIL GAS SURVEY 9/15/92-10/6/92
- 200* SOIL VAPOR PIEZOMETER SAMPLE RESULTS 12/92
- ND NON DETECT

FIGURE 4-2a
VADOSE ZONE PCE CONCENTRATIONS
FROM 20 FEET BGS
 DAVIS GLOBAL COMMUNICATIONS SITE
 McCLELLAN AIR FORCE BASE
 YOLO COUNTY, CALIFORNIA



- FIGURE 4-21**
VADOSE ZONE PCE CONCENTRATIONS
FROM 30 FEET BGS
DAVIS GLOBAL COMMUNICATIONS SITE
MCLELLAN AIR FORCE BASE
YOLO COUNTY, CALIFORNIA

Table 4-4

Mass Estimates for the Vadose Zone (0 to 40 ft bgs)

Polygon No.	Area (ft ²)	Soil Depth Interval (ft bgs)	Soil Volume (ft ³)	Mass of Soil (kg)	Total VOC Concentration (µg/kg)	Mass of VOCs (gr)	Mass of VOCs (kg)	Mass of VOCs (lb)
1	2,600	0-5	13,000	534,000	20.46	10.93	0.01	0.02
		6-10	13,000	534,000	76.36	40.78	0.04	0.09
		11-25	39,000	1,603,000	40.29	64.58	0.06	0.14
		26-40	39,000	1,603,000	983.77	1,576.98	1.58	3.47
2	2,200	0-5	11,000	452,000	0.48	0.22	0.00	0.00
		6-10	11,000	452,000	638.31	288.52	0.29	0.64
		11-25	33,000	1,356,000	526.99	714.60	0.71	1.57
		26-40	33,000	1,356,000	621.30	842.48	0.84	1.86
3	4,200	0-5	21,000	863,000	0.41	0.35	0.00	0.00
		6-10	21,000	863,000	53.95	46.56	0.05	0.10
		11-25	63,000	2,589,000	184.34	477.26	0.48	1.05
		26-40	63,000	2,589,000	389.24	1,007.74	1.01	2.22
4	1,500	0-5	7,500	308,000	183.04	56.38	0.06	0.12
		6-10	7,500	308,000	0.00	0.00	0.00	0.00
		11-25	22,500	925,000	425.33	393.43	0.39	0.87
		26-40	22,500	925,000	557.13	515.35	0.52	1.13
5	6,100	0-5	30,500	1,253,000	3.80	4.76	0.00	0.01
		6-10	30,500	1,253,000	96.97	121.50	0.12	0.27
		11-25	91,500	3,760,000	6.02	22.64	0.02	0.05
		26-40	91,500	3,760,000	1.21	4.55	0.00	0.01
6	25,800	0-5	129,000	5,301,000	6.51	34.51	0.03	0.08
		6-10	129,000	5,301,000	58.61	310.69	0.31	0.68
		11-25	387,000	15,902,000	18.19	289.26	0.29	0.64
		26-40	387,000	15,902,000	557.10	8,859.00	8.86	19.5
7	7,900	0-5	39,500	1,623,000	149.34	242.38	0.24	0.53
		6-10	39,500	1,623,000	32.56	52.84	0.05	0.12
		11-25	118,500	4,869,000	0.00	0.00	0.00	0.00
		26-40	118,500	4,869,000	557.10	2,712.52	2.71	5.97
8	53,500	0-5	267,500	10,992,000	0.00	0.00	0.00	0.00
		6-10	267,500	10,992,000	8.29	91.12	0.09	0.20
		11-25	802,500	32,976,000	0.00	0.00	0.00	0.00
		26-40	802,500	32,976,000	557.10	18,370.93	18.37	40.5
9	15,000	0-5	75,000	3,082,000	0.00	0.00	0.00	0.00
		6-10	75,000	3,082,000	9.53	29.37	0.03	0.06
		11-25	225,000	9,245,000	1.80	16.64	0.02	0.04
		26-40	225,000	9,245,000	621.30	5,743.92	5.74	12.6
10	4,300	0-5	21,500	883,000	0.00	0.00	0.00	0.00
		6-10	21,500	883,000	26.98	23.82	0.02	0.05
		11-25	64,500	2,650,000	0.00	0.00	0.00	0.00
		26-40	64,500	2,650,000	621.30	1,646.45	1.65	3.63
11	8,100	0-5	40,500	1,664,000	0.00	0.00	0.00	0.00
		6-10	40,500	1,664,000	0.69	1.15	0.00	0.00
		11-25	121,500	4,993,000	0.00	0.00	0.00	0.00
		26-40	121,500	4,993,000	1.21	6.04	0.01	0.01
Totals	131,200			215,646,000	8,037.01	44,620.25	44.62	98.3

Estimating the mass of contaminants in the saturated zone requires two basic data sets:

- Data on the physical characteristics of the aquifers and aquitards of interest (e.g., area, thickness, porosity, soil density, fractional organic carbon content [f_{oc}]).
- Data on the contaminant characteristics in the aquifers of interest (e.g., contaminant concentration, contaminant distribution, water-organic carbon distribution coefficient [K_{oc}]).

To estimate the mass present, each aquifer target area was subdivided into polygons. The polygons were centered around monitoring well locations within the aquifer of interest. Contamination is present in two forms: dissolved in the groundwater and sorbed onto the aquifer or aquitard materials. The aqueous concentration data were used to estimate the amount of sorbed contamination using equilibrium equations. The mass of contamination was estimated for each polygon within each aquifer. The aquitard contamination was estimated using an average of the aqueous concentration from the aquifer above and below the aquitard. The area of the aquitard was assumed to equal the area of the underlying aquifer.

Table 4-5 on the following page gives the estimated mass of contamination per SCOC for each aquifer and aquitard. The total estimated mass of contamination in the saturated zone is 280 kg (617 lb). PCE, tri-chloroethene (TCE), and 1,1-DCE account for more than 88 percent of the total mass present in the saturated zone beneath the site. Almost 85 percent of the total mass is present above the C-D aquitard beneath the site.

4.3 Fate and Transport

4.3.1 Contaminant Properties

Chemical and physical properties of the SCOCs govern the fate and transport of each compound. The potential for contaminants to migrate in the vadose zone and groundwater depends primarily on the following properties:

Chemical

- Vapor pressure
- Solubility in water
- Organic carbon partition coefficient
- Henry's constant
- Inorganic sorption

Table 4-5
Groundwater Mass Estimate (kg)

SCOC	A-B	B	B-C	C	C-D	D	D-E	E
Dissolved								
Tetrachloroethene (PCE)	10.50	11.20	6.10	0.40	0.70	1.0	1.0	0.00
Trichloroethene (TCE)	7.80	8.30	6.10	4.30	4.1	3.7	1.50	0.10
1,1-Dichloroethene	2.10	2.20	11.3	23.0	15.8	7.2	2.9	0.00
Benzene	0.02	0.02	0.03	0.00	0.00	0.00	0.00	0.00
Vinyl Chloride	1.30	1.40	1.70	0.00	0.00	0.00	0.00	0.00
1,1-Dichloroethane	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
1,2-Dichloroethene	6.90	7.30	4.10	0.80	0.70	0.40	0.30	0.00
Total (kg)	28.62	30.43	29.33	28.50	21.30	12.30	5.70	0.10
Total (lb)	63.11	67.10	64.67	62.84	46.97	27.12	12.57	0.22
Percent of Total	0.18	0.19	0.19	0.18	0.14	0.08	0.04	0.00
Sorbed								
Tetrachloroethene (PCE)	25.00	37.00	14.3	0.06	0.80	1.3	0.50	0.00
Trichloroethene (TCE)	6.30	9.40	5.0	2.0	1.7	1.6	0.60	0.03
1,1-Dichloroethene	0.90	1.30	2.1	2.5	1.5	0.7	0.30	0.00
Benzene	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Vinyl Chloride	0.07	0.09	0.08	0.00	0.00	0.00	0.00	0.00
1,1-Dichloroethane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1,2-Dichloroethene	2.60	3.50	1.4	0.20	0.10	0.06	0.05	0.00
Total (kg)	34.88	51.30	22.89	5.30	4.1	3.66	1.45	0.03
Total (lb)	76.91	113.12	50.47	11.69	9.04	8.07	3.20	0.07
Percent of Total	0.28	0.42	0.19	0.04	0.03	0.03	0.01	0.00
Contaminant Summary								
Contaminant	Dissolved	Sorbed	Total	Percent of Total Mass	Percent of Total Dissolved Mass	Percent of Total Sorbed Mass		
Tetrachloroethene (PCE)	30.90	79.5	110.4	0.394	0.198	0.643		
Trichloroethene (TCE)	35.90	26.6	62.5	0.223	0.231	0.215		
1,1-Dichloroethene	64.5	9.3	73.8	0.264	0.413	0.075		
Benzene	0.07	0.03	0.10	0.000	0.000	0.000		
Vinyl Chloride	4.40	0.24	4.64	0.017	0.028	0.002		
1,1-Dichloroethane	0.01	0.00	0.01	0.000	0.000	0.000		
1,2-Dichloroethene	20.50	7.91	28.4	0.102	0.131	0.064		
Total (kg)	156.3	123.61	28.0	1.000	1.000	1.000		
Total (lb)	344.64	272.56	617.40					

Physical

- Organic carbon content of the soil
- Moisture content
- Porosity
- Bulk density
- Hydraulic gradient
- Water flux in the vadose zone
- Average interstitial groundwater velocity in the saturated zone

4.3.1.1 Chemical Properties

The values of each of the chemical properties for the SCOCs are given in Table 4-6. The following paragraphs summarize the importance of each of the chemical properties when considering potential contaminant movement.

Table 4-6 Chemical Properties of SCOCs				
SCOC	Vapor Pressure (mm Hg)	Water Solubility (mg/l @ 20° C)	Organic Carbon Partition Coefficient (cm ³ /gm)	Henry's Constant (atm m ³ /mole)
PCE	14	150	364*	0.0227
TCE	59	1,000	126	0.0089
1,1 DCE	500	400	65	0.154
Benzene	76	1,780	65	0.0054
Vinyl Chloride	2,300	1,100	8	0.695
1,1-DCA	180	5,500	30	0.0057
trans-1,2-DCE	265	6,300	59	0.0066
*Schwille, 1988. Source: EPA, 1990.				

Vapor Pressure. The vapor pressure of a given substance is the partial pressure of vapor in equilibrium with a pure liquid at a given temperature. It indicates the volatilization potential of a compound. The higher the vapor pressure, the more likely the compound will enter the vapor phase. Of the SCOCs, vinyl chloride has the highest vapor pressure at standard temperature. The vapor pressure is more of an important consideration when contamination has been identified to exist in a free phase liquid form (dense nonaqueous phase liquids [DNAPLS]). The presence

of DNAPLS has not been confirmed at the Davis Global Communications Site (Davis Site).

Solubility in Water. The water solubility indicates the maximum concentration that can be attained at 20 degrees C when each compound is dissolved in water. The solubility limit is an important consideration in contaminant transport via groundwater or pore water in the vadose zone because it dictates the amount of contaminant found in solution and whether DNAPLS will exist. Of the SCOCs, 1,2-dichloroethene (DCE) has the highest solubility in water, and PCE has the lowest solubility.

Organic Carbon Coefficient (K_{oc}). The organic carbon partition coefficient indicates the sorption capacity of the compound to the organic carbon in the soil matrix and therefore its potential for movement during contaminant transport. The higher the K_{oc} , the more the compound is adsorbed to a given amount of organic carbon exchange sites in the soil matrix and the less is available for transport. Of the SCOCs, PCE has the highest K_{oc} value, and vinyl chloride has the lowest value.

Henry's Constant. The ability of a compound to volatilize from water depends on its Henry's constant. The higher the Henry's constant, the more a compound is likely to volatilize from contaminated groundwater or pore water and move into the soil-gas-filled pores of the vadose zone. Of the SCOCs, vinyl chloride has the greatest ability to volatilize from water while 1,1-dichloroethane and benzene have the lowest ability to volatilize. Volatilization can lead to contamination of the soil and soil gas above contaminated groundwater.

Inorganic Sorption. In the absence of a significant organic carbon content in aquifer material, mineral surfaces may exist that are exposed directly to the solution rather than being coated with an organic carbon film. These surfaces have some capacity for adsorbing contaminants. The amount of surface area available for adsorption is an important variable in determining the sorption capacity. Relatively small amounts of clay minerals in an aquifer material can account for a significant proportion of a material's surface area because of the small size and the sheet structure of the clays. Different clay minerals have different unit surface areas. Kaolinitic clays have surface areas on the order of 10 m²/g, while micas and chlorites have about 100 m²/g, and montmorillonitic clays can have as much as 800 m²/g.

4.3.1.2 Physical Properties

The physical properties of the vadose zone (and several of the saturated zone) were measured during the remedial investigation. Table 4-6 gives the range of values for the measured physical properties. Hydraulic gradients for the saturated zone and interstitial pore velocity were excluded from Table 4-7 because they vary from season to season and between different aquifers.

Table 4-7 Physical Properties at Davis Site	
Physical Property	Range of Values
Organic Carbon Content, f_{oc}	0.0007 to 0.0029
Moisture Content (%)	0.15 to 0.25
Porosity (%)	0.35 to 0.39
Bulk Density (gm/cm ³)	1.4 to 1.55

4.3.2 Transport Mechanisms

The ability of contaminants to migrate in the vadose zone depends on the chemical and physical properties listed above. However, contaminant transport in the vadose zone most likely occurs through one of four mechanisms: liquid advection, sorption/desorption aided by fluctuating groundwater, gaseous diffusion, and volatilization. These mechanisms are discussed in more detail in Appendix H, Analysis of Vadose Zone Contamination Impacts. The ability of contaminants to migrate in the groundwater flow system depends primarily on the rate of groundwater movement. The mechanisms are discussed in the following paragraphs.

4.3.2.1 Liquid Advection

Liquid advection is the process of water in the vadose zone percolating downward to the water table. The rate of advection is governed by the recharge rate and residual water content of the vadose zone. Preferential pathways within the vadose zone will tend to concentrate both liquid and vapor flow and reduce transport times to less than those predicted from bulk soil properties. During drilling of the SVMWs, macropores were discovered to exist in the soil matrix dominated by clay. A macropore is defined as a large-diameter pore space (typically several orders of magnitude larger than average pore size) extending either horizontally or vertically within the soil matrix. Macropores were created by the decay and disintegration of plant material that was covered by fluvial deposition during periods of flooding of the historic Putah Creek channel. Preferential advective flow typically occurs through macropores. It appeared that flow through these macropores was occurring. Most of the macropores were noted in the area of the former underground fuel tanks and residual petroleum hydrocarbon contamination was discovered in the macropores (see Appendix Q, Lithologic and Geophysical Logs).

4.3.2.2 Sorption/Desorption

Sorption/desorption is the process by which contaminant mass is exchanged between the liquid phase and the solid phase. This may be a dominant mechanism for contaminant transport at the Davis Site at the vadose zone/saturated zone interface. Because of the seasonality of a portion of the vadose zone where residual contamination exists, rising groundwater levels have the potential to facilitate contaminant desorption

from the soil. Once the contamination transforms to the aqueous phase, it has the potential to move laterally with the moving groundwater.

4.3.2.3 Gaseous Diffusion

Gaseous diffusion is the transfer of contaminant in the gas phase into adjacent cells driven by a concentration gradient. This can be a dominant transport mechanism in areas of low surface recharge and extensive vadose zones. It likely plays a less active role in subsurface contaminant transport at the Davis Site in comparison to liquid advection and sorption/desorption.

4.3.2.4 Volatilization

Volatilization is the process by which contaminant mass is exchanged between the liquid phase and the gaseous phase. The direction and magnitude of this exchange are estimated by Henry's constant. This probably plays a minor transport role at the Davis Site.

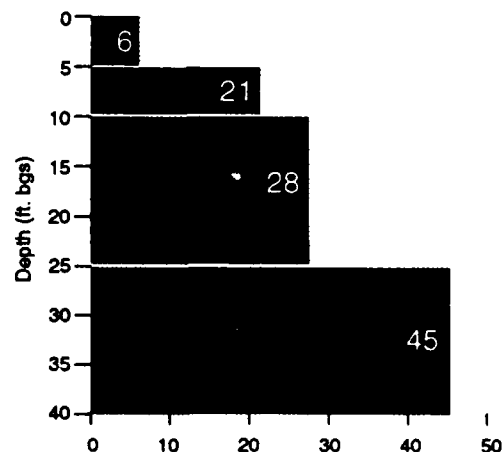
4.3.3 Vadose Zone Transport

Downward vadose zone contaminant transport is dominated by liquid advection at the Davis Site (see Appendix H). Therefore, the water solubility and K_{oc} play an important role in the potential for contaminant transport. The future impacts to groundwater based on existing soil gas contamination were estimated using a one-dimensional finite difference computer model called VLEACH (Appendix H). The data presented in Table 4-2 show that the vadose zone contaminant mass is dominated by PCE. Therefore, only the PCE concentrations were input into VLEACH to estimate the mass of contamination moving to the groundwater over time.

Approximately 45 percent of the contaminant mass estimated for the vadose zone is found between 26 and 40 feet bgs (see Figure 4-3). Because of this distribution of mass, the initial contaminant loading to the groundwater is the highest. The initial PCE loading to the groundwater is estimated at 450 grams/year (g/yr). This loading exponentially decays over time to a value of approximately 20 g/yr after 200 years.

The impact to groundwater of this loading was calculated by estimating the groundwater underflow beneath the site and then performing mixing cell calculations to determine the concentration of PCE in the groundwater over time. The initial PCE concentration in groundwater was set equal to zero. The maximum incremental impacts to the groundwater from the PCE residing in the vadose zone ranged from 20 $\mu\text{g/l}$ to 80 $\mu\text{g/l}$ after 30 years. These values are above the groundwater MCL for PCE of 5 $\mu\text{g/l}$. The PCE remains a source of contamination for over 200 years. Therefore, the mass of PCE contamination that now resides in the vadose zone is a significant long-term threat to the groundwater quality beneath the Davis Site.

Figure 4-4 is a schematic flow chart of the potential VOC transport at the Davis Site. The schematic outlines the fate and transport of a PCE- or



**FIGURE 4-3
VADOSE ZONE
CONTAMINANT MASS (%)**

TCE-free product spill at the ground surface and follows potential pathways to the groundwater. The schematic provides a conceptual understanding of the dominant transport mechanisms available at the site. It is also a basis for understanding and explaining the occurrence of the measured soil gas and aqueous phase concentrations of the SCOCs beneath the site. This schematic complements the interpretation of the contaminant data on the cross-sections provided at the end of this chapter.

Figure 4-5 shows some of the possible pathways that PCE and TCE can be degraded by chemical and biological processes. Figure 4-4 presents the equilibrium partitioning of PCE and associated breakdown products in the vadose zone and groundwater based on the chemical properties presented in Table 4-5. In Figure 4-4, the higher the degree of shading, the higher the percentage of a given mass of compound is likely to exist at equilibrium in that form. The thickness of the arrows indicates the dominant transport pathway or mechanism.

Following the PCE pathway in Figure 4-4, it is seen that as free product enters the vadose zone, most of the PCE will reside as sorbed to exchange sites on the soil. This is driven by the relatively low solubility of PCE and relatively high K_{oc} . At equilibrium in the vadose zone, approximately 75 percent of the original mass of PCE will reside in the sorbed phase while the remaining mass will reside as either soil gas, free product, or be dissolved in pore water. This is consistent with the soil gas sampling results where PCE mass dominates the vadose zone contaminant mass.

Movement of the PCE contamination within the vadose zone is dominated by liquid advection to the groundwater. Once in contact with groundwater, sorption/desorption is the primary mechanism for transport. Groundwater level fluctuation plays a major role in contaminant movement at the site because of the sorption/desorption process that takes place at the groundwater/vadose zone interface. Without the seasonal fluctuation, it is likely that more contamination would still reside in the vadose zone.

Figure 4-4 also illustrates how this transport process could be completed with TCE and 1,1-DCE. It is obvious that the transport or transformation of contamination within the subsurface is dependent on subsurface conditions. PCE, TCE, and 1,1-DCE account for over 97 percent of the vadose zone contaminant mass in the site soil gas (see Table 4-3) with PCE accounting for over 90 percent of the mass. Within the site groundwater, PCE, TCE, and 1,1-DCE account for 85 percent of the contamination with PCE accounting for over 56 percent of the mass.

The type and volume of the source of contamination at this site is unknown. Therefore, it is unknown if the presence of PCE and TCE degradation products like 1,1-DCE, 1,2-DCE, and vinyl chloride are the result of chemical or biodegradation within the subsurface or representative of the compound's movement from a vadose zone source area to the groundwater. Biodegradation potential within the groundwater is discussed in Appendix N, Natural Biological Groundwater Attenuation, and will be discussed later in this chapter.

PCE, TCE, and 1,1-DCE account for over 97 percent of the vadose zone contaminant mass.

4.3.4 Groundwater Transport

The ability of contaminants to migrate in the groundwater flow system depends primarily on their extent of adsorption (illustrated in Figure 4-4). The K_d of a compound gives an indication of the sorptive tendency of a compound. It is assumed that organic carbon is the primary adsorbent in the subsurface media. For subsurface materials with low organic carbon content, significant adsorption by subsurface minerals is also possible. According to the K_d values, vinyl chloride is the most mobile compound at this site, while PCE is the least mobile.

The mass of contamination within each subsurface zone beneath the Davis Site is presented in Table 4-5. The mass of contamination in the groundwater accounts for over 86 percent of the total estimated site contamination. Dissolved contaminant concentrations from groundwater samples taken during February and July 1993 are shown in the cross-section figures at the end of this chapter and are the basis of the mass estimates. The cross sections aid in the understanding of the mechanics of contaminant flow potential beneath the site.

The contaminant transport pathways beneath the Davis Site are driven by the following physical properties:

- Varying horizontal and vertical gradients
- Varying flow directions
- Fluctuating groundwater levels
- Localized aquifer heterogeneities

The direction of contaminant flow will typically mirror the groundwater flow direction. Horizontal and vertical gradients are steepest during the summer months beneath the site. For this reason, the quantity of groundwater flow and dissolved contamination is highest during this time period. Within the B and C aquifers, the flow direction is generally southerly (it ranges from southwest to southeast) during the summertime. During the winter months, the groundwater flow direction varies from southwest to northwest with the gradient being up to an order-of-magnitude less than that during the summer. Therefore, contaminant movement during winter months is less than during summer months.

Contaminant movement is typically slower than bulk groundwater flow because of retardation of contaminant flow by adsorption and other physical and chemical processes. Assuming that contamination within the groundwater moves at the same rate as groundwater would typically overestimate the rate of contaminant movement.

4.3.4.1 Concentration Changes

Concentration versus time plots are presented in Figures 4-6a through 4-6h. The plots present the historical contaminant concentration data for the detected SCOCs for Wells MW-1, MW-3, MW-5, MWC-12, MWD-12, MWC-3, MWD-3, and MWD-10. Other time series plots are presented in Appendix E. Concentration versus time plots for all wells using a log scale for concentration are provided in Attachment 1 of the

Historically, B aquifer Wells MW-3, MW-2, and MW-1 contain groundwater with the highest level of TCE concentrations.

levels of SCOCs over time. Groundwater elevations are presented on the figures to examine any trends associated with rising and falling groundwater levels.

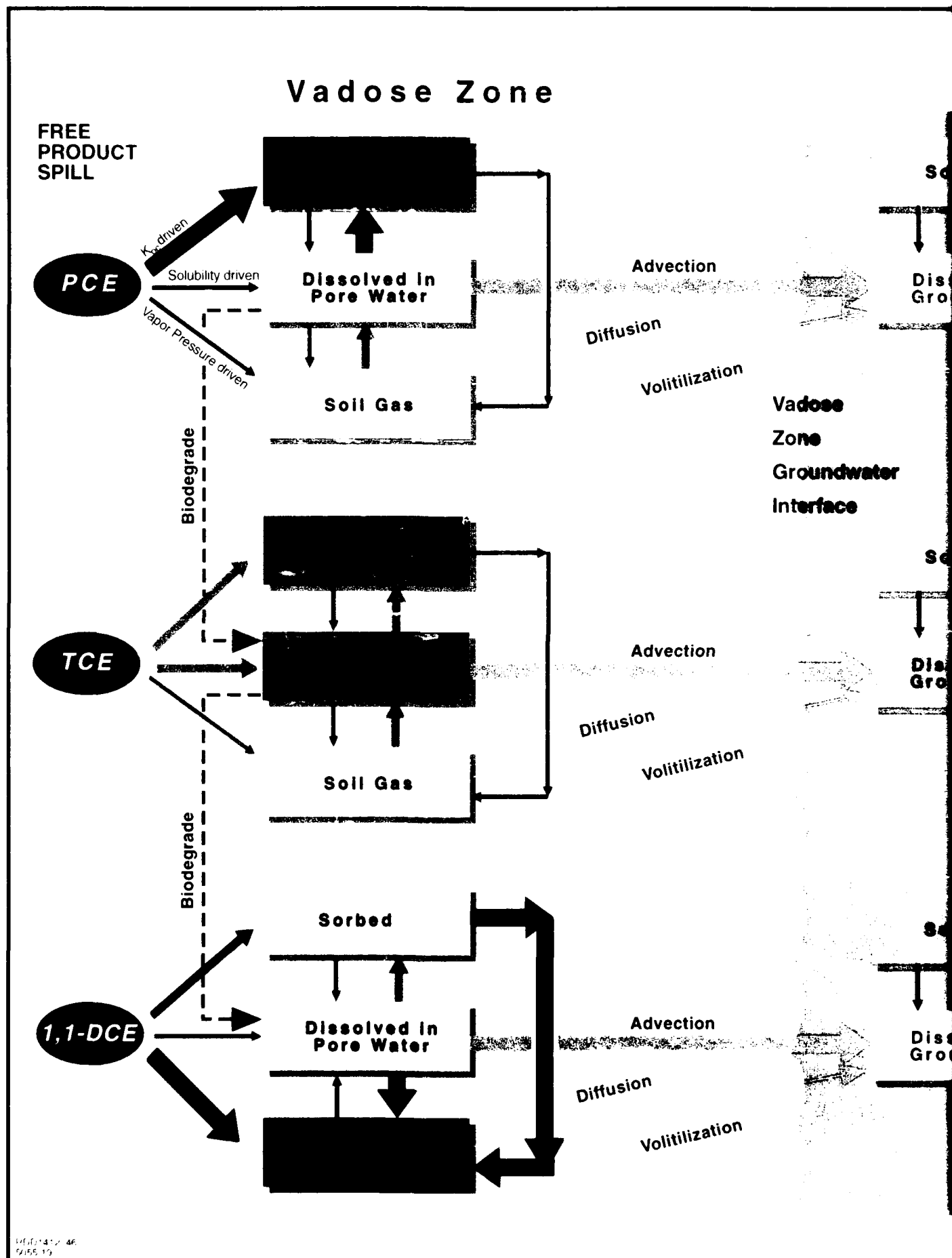
The initial groundwater sampling from these wells showed concentrations in excess of 1,000 µg/l. TCE concentrations after the initial sampling (3 months later) decreased by at least threefold from the initial sampling. The reason for this decrease is unknown. The initial TCE concentrations were not used in the mass estimate comparison between 1988 and 1993.

To investigate the change in dissolved contaminant mass over time in the B aquifer, the mass of contamination within the B aquifer was estimated using May 1988 and February 1993 sampling results from Wells MW-1 through MW-8. The results of the contaminant mass comparison are shown in Table 4-8. The results show that the dissolved mass of contamination within the B aquifer in 1993 is about half of the total mass present during May 1988. Samples from Wells MW-1 and MW-5 showed the greatest decrease in mass while samples from Well MW-3 showed the only increase in contaminant mass. Well MW-3 is down-gradient from Well MW-5 during most of the year. The increase in contaminant mass in this well probably represents contaminant movement by means of groundwater flow at the site.

Only the B aquifer mass was estimated for 1988 because of the longer period of historical data for this zone when compared to the C and D aquifers at the site. Contaminant concentrations within the C and D aquifers have increased since monitoring wells were installed in 1991. Groundwater from Monitoring Wells MWD-10 and MWD-12 is becoming more concentrated with TCE over time. Levels of TCE contamination within the C aquifer are higher than those in the D aquifer.

One reason for the increase in contamination in the C and D aquifers is because of vertical contaminant movement beneath the site. Careful examination of cross-sections B-B' (Figure 4-10) and H-H' (Figure 4-16) reveal a potential conduit for contaminant movement between the shallow more contaminated groundwater and the underlying more transmissive C and D aquifers. The zone of highest contamination is found in the vicinity of Wells MW-2, EW-1B, and MW-3. This area seems to have the greatest thickness of B aquifer materials and contamination may tend to concentrate in this area. During summer months when horizontal and vertical gradients are greatest, contamination from the B aquifer moves southerly and downward to a transmissive zone in the C aquifer in the vicinity of MWC-3 where it intersects the upper reaches of the D aquifer. From this point, it reaches the more transmissive D aquifer and spreads laterally and downward to the E aquifer.

Horizontal gradients within the B and C aquifers favor this southerly movement while steep downward gradients exacerbate the spread of contamination. The outcome is continued movement of contaminated



Groundwater

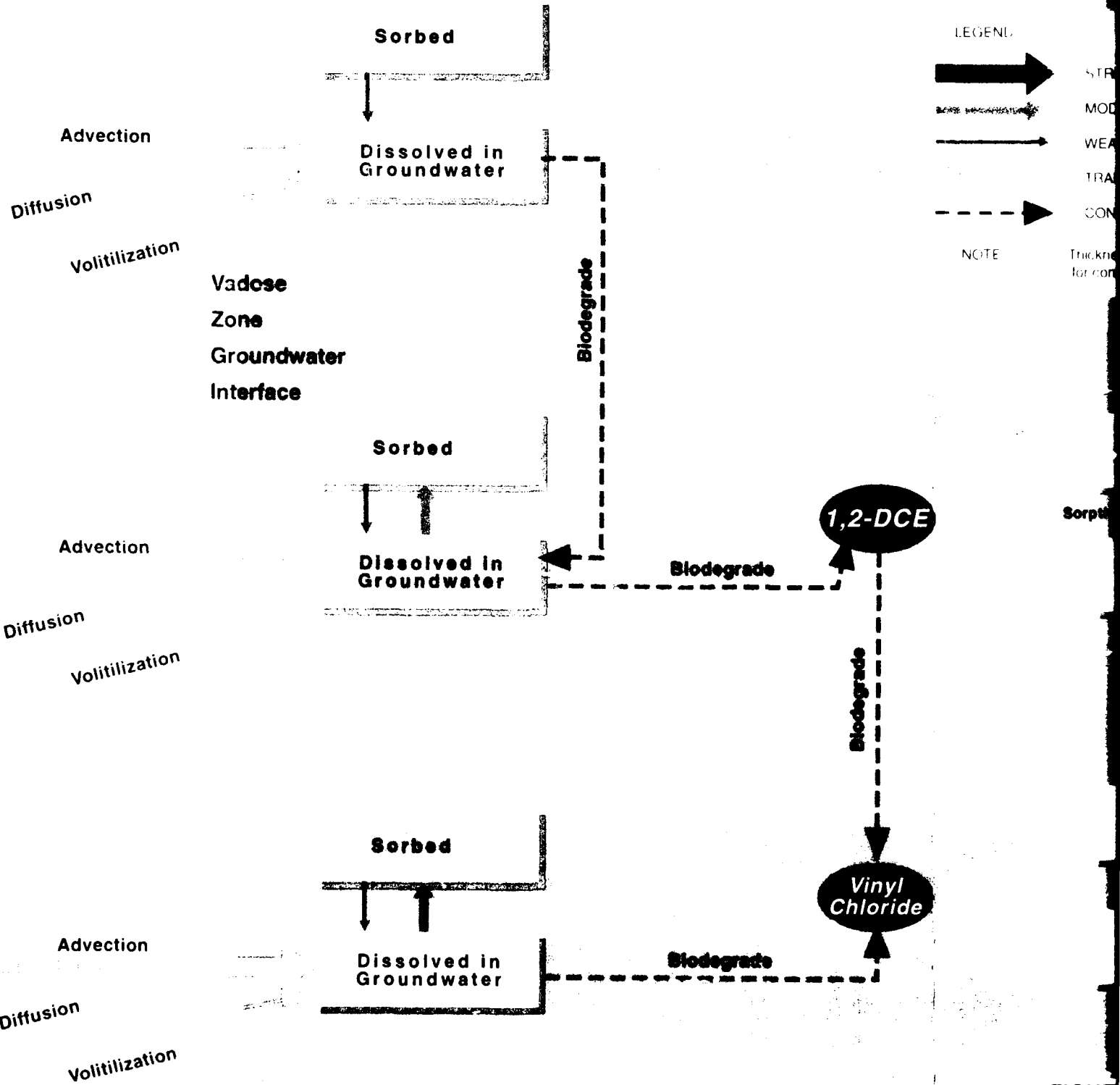


FIGURE 1
GROUNDWATER FLOW AND TRANSPORT
 DAVIS, GLENN
 McCLELLAN
 YOLO COUNTY

Groundwater

LEGEND



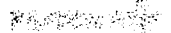
STRONG TENDENCY



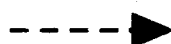
MODERATE TENDENCY



WEAK TENDENCY



TRANSPORT MECHANISM



CONDITION DEPENDENT

NOTE

Thickness of arrows indicates tendency for compound to partition to that phase

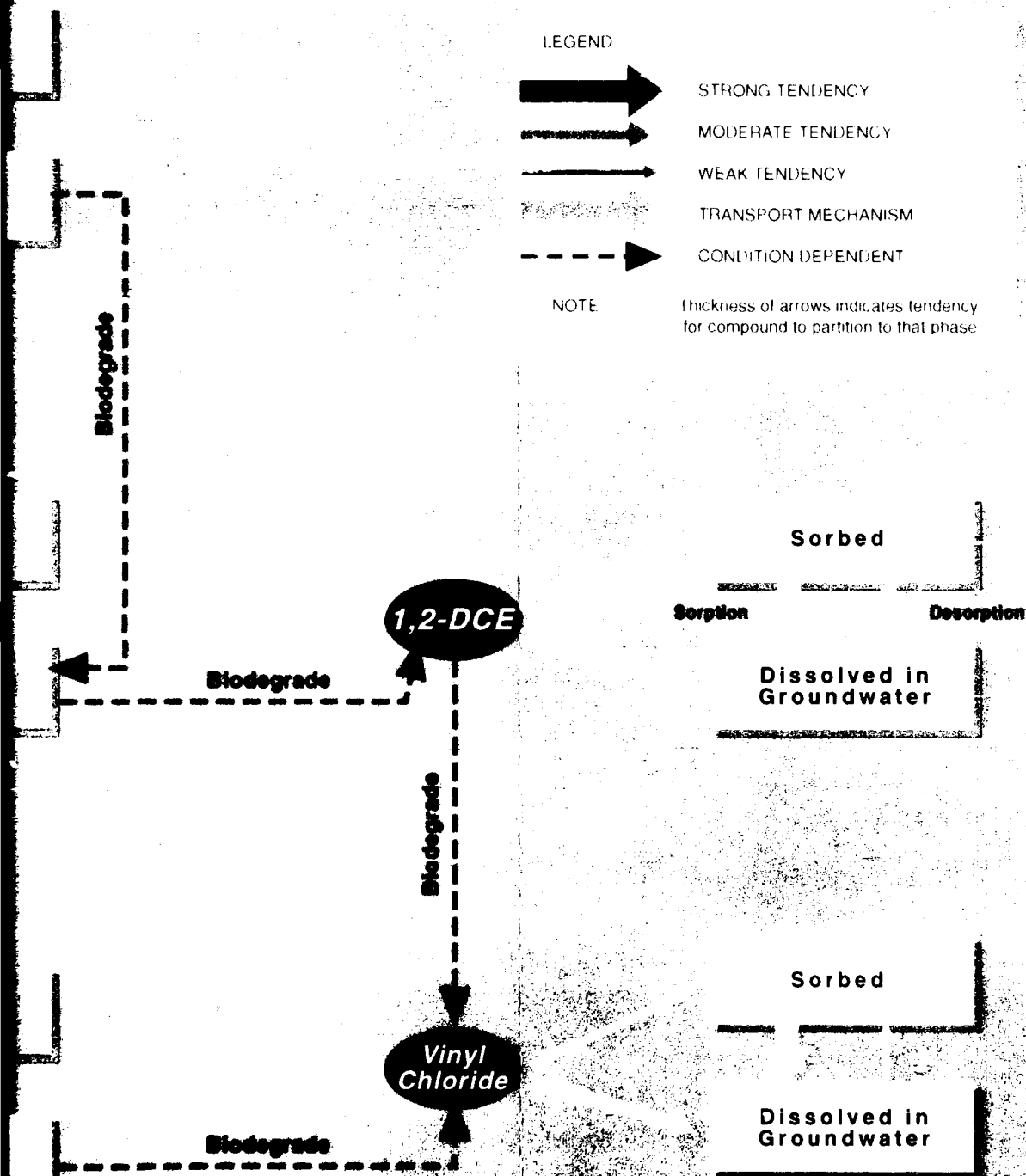


FIGURE 4-4
FLOW CHART SCHEMATIC OF VOC
TRANSPORT AT DAVIS SITE
 DAVIS GLOBAL COMMUNICATIONS SITE
 MCCLELLAN AIR FORCE BASE
 YOLO COUNTY, CALIFORNIA

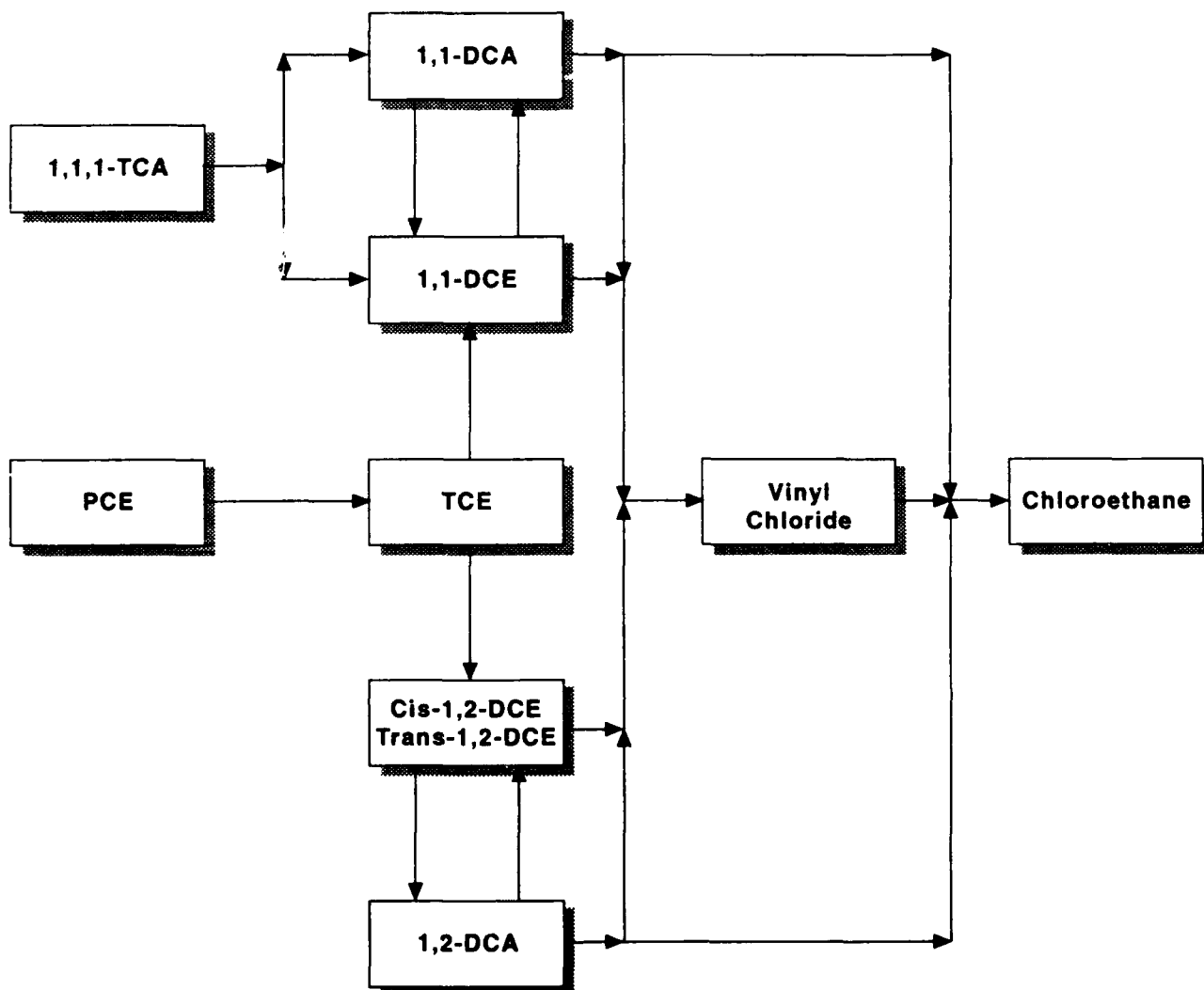
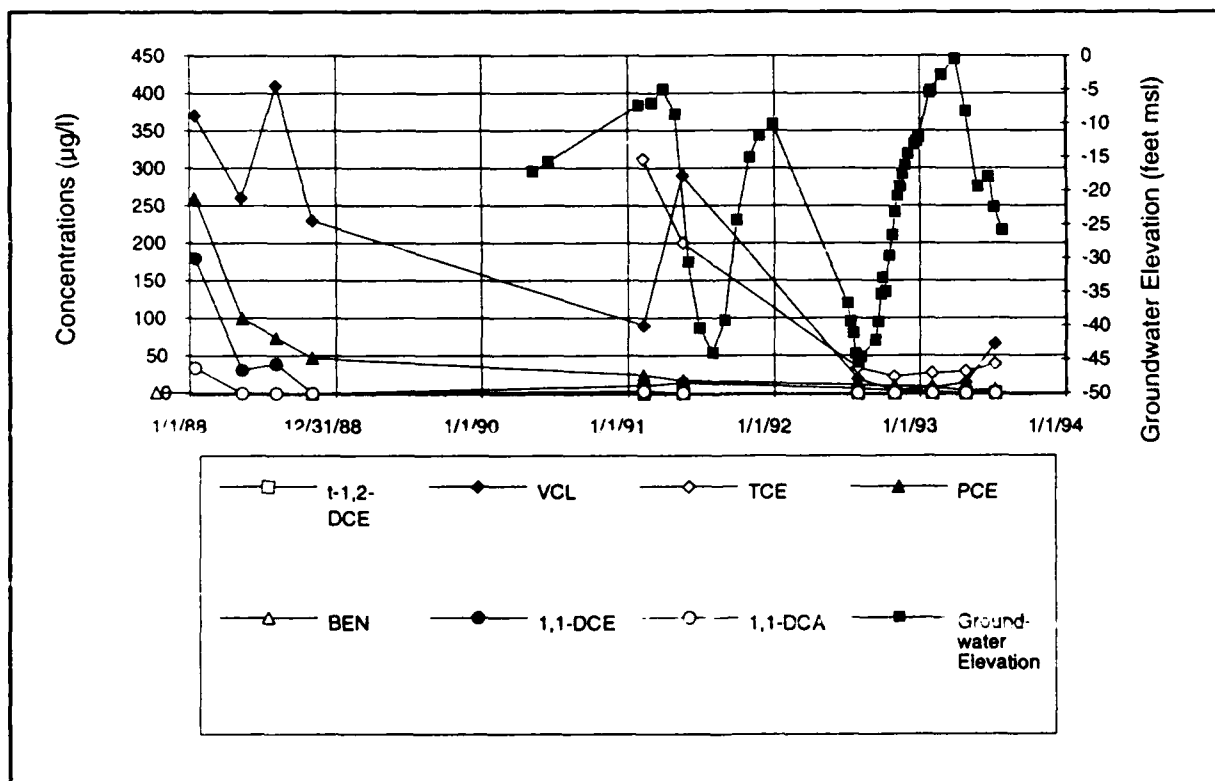
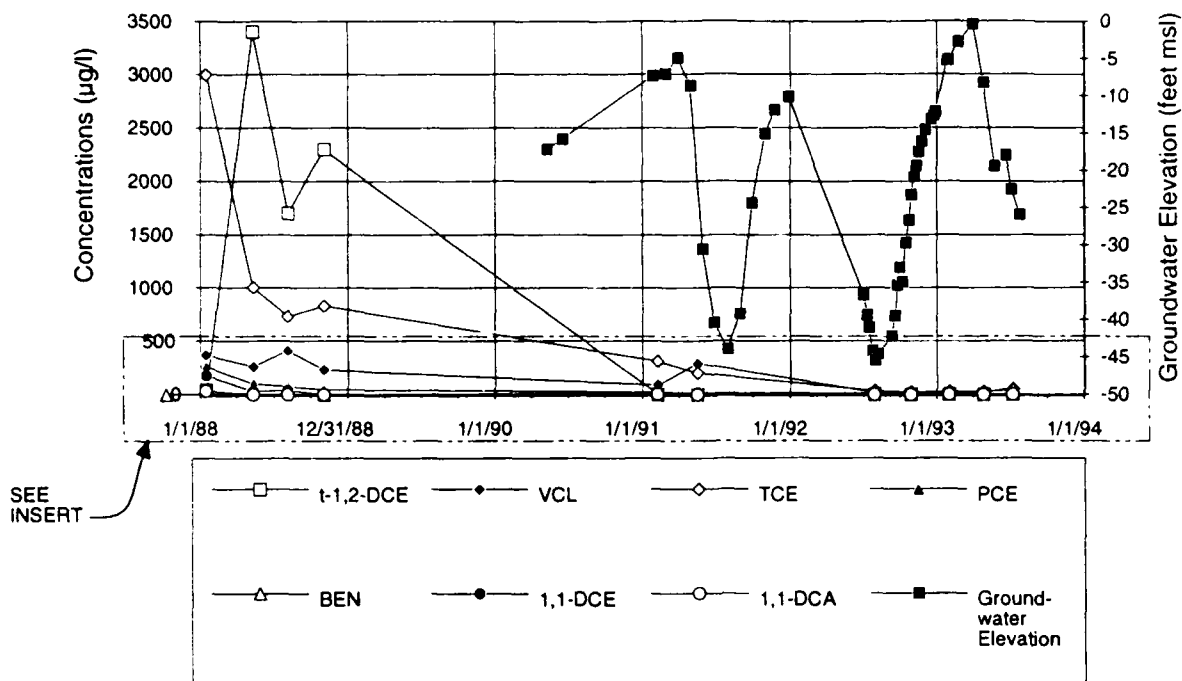
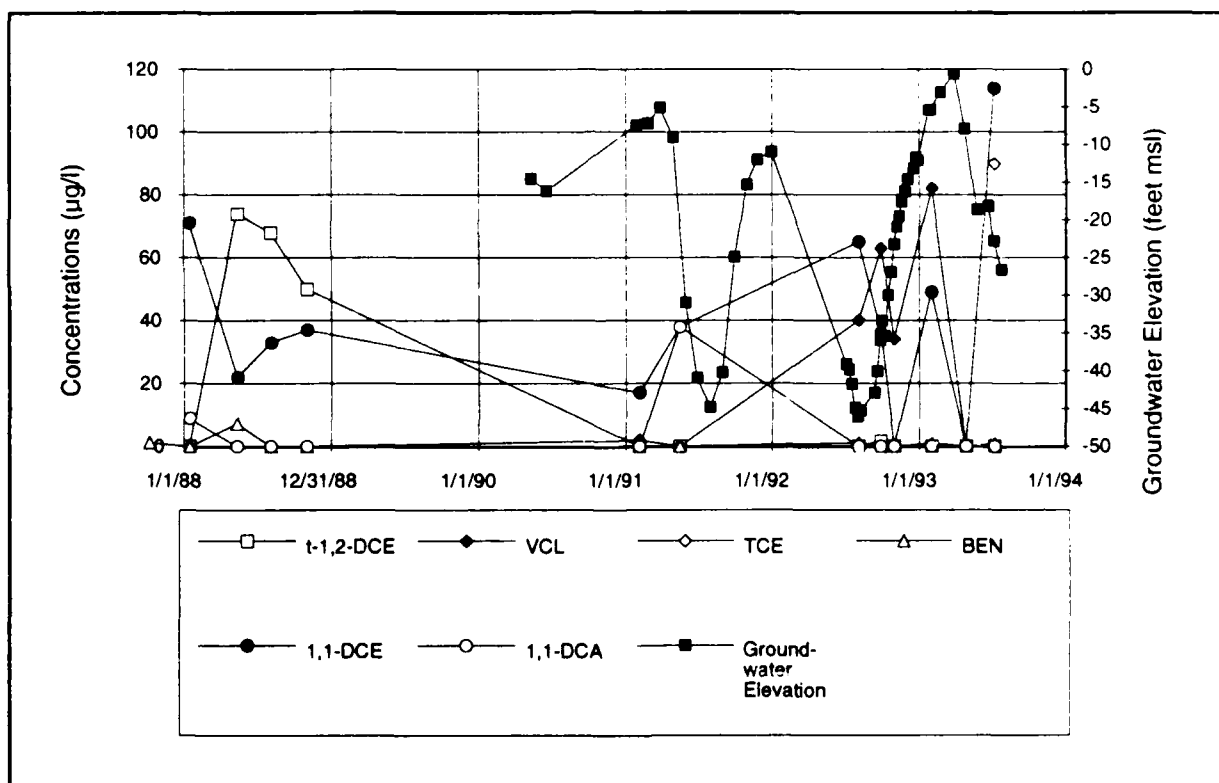
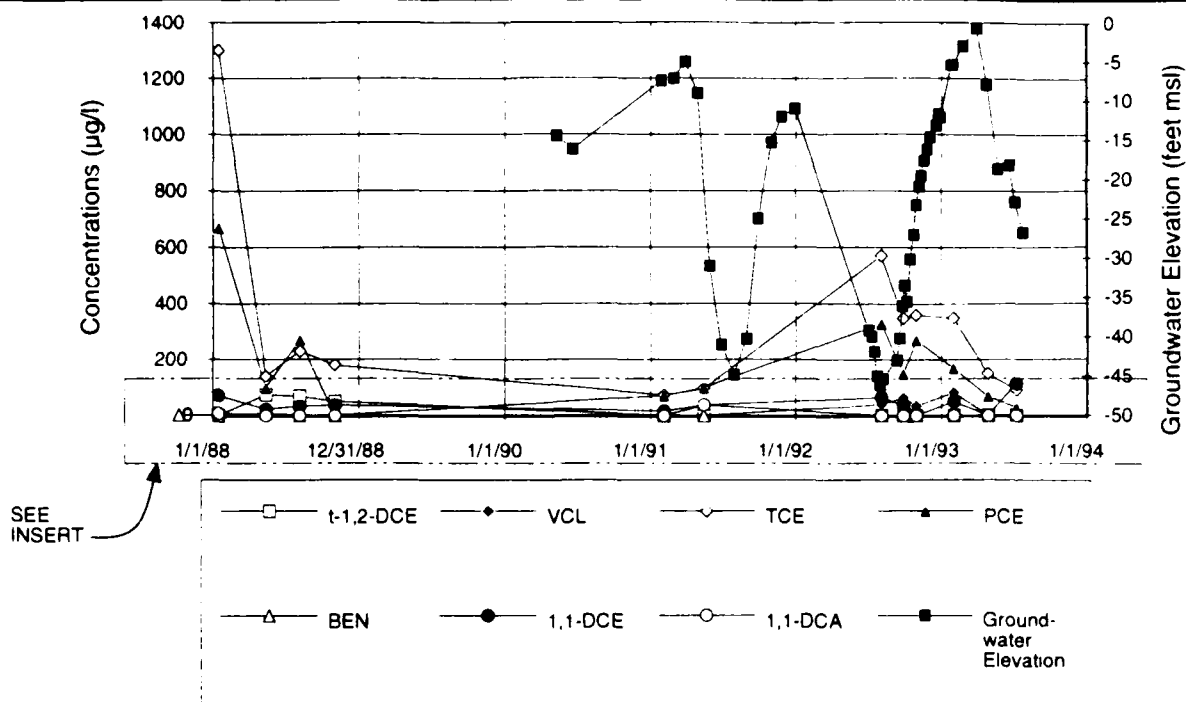


FIGURE 4-5
POTENTIAL TRANSFORMATION
PRODUCTS FOR CONTAMINANTS
FOUND AT THE DAVIS SITE
DAVIS GLOBAL COMMUNICATIONS SITE
McCLELLAN AIR FORCE BASE
YOLO COUNTY, CALIFORNIA



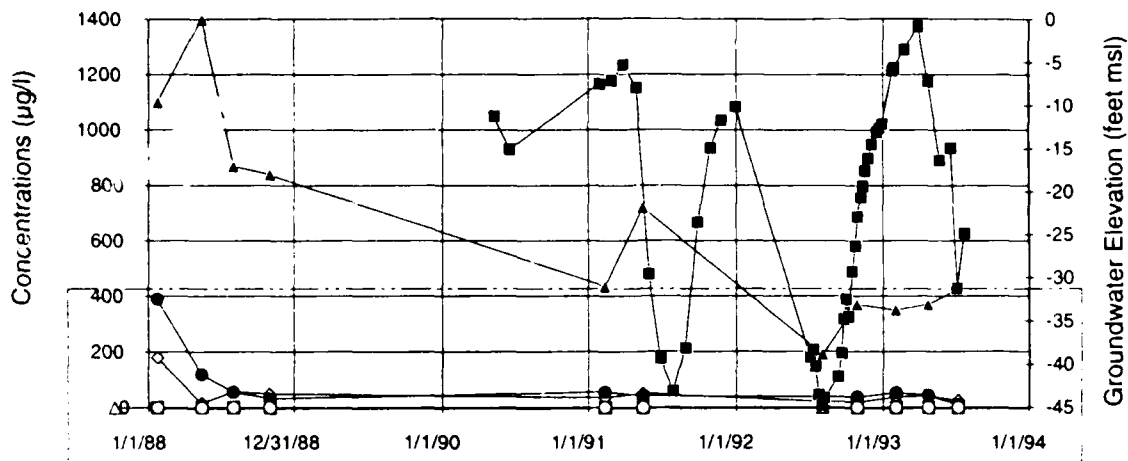
INSERT

FIGURE 4-6a
COC TIME CONCENTRATION
PLOT FOR MW-1
 DAVIS GLOBAL COMMUNICATIONS SITE
 MCCLELLAN AIR FORCE BASE
 YOLO COUNTY, CALIFORNIA

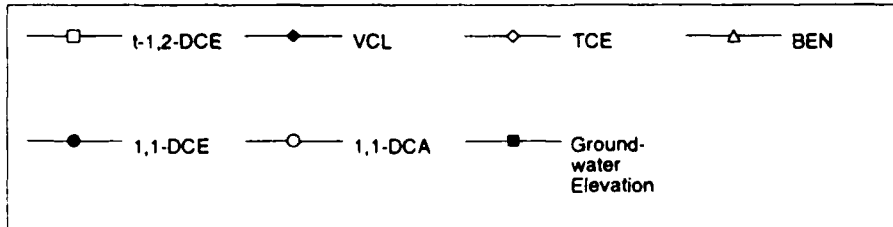
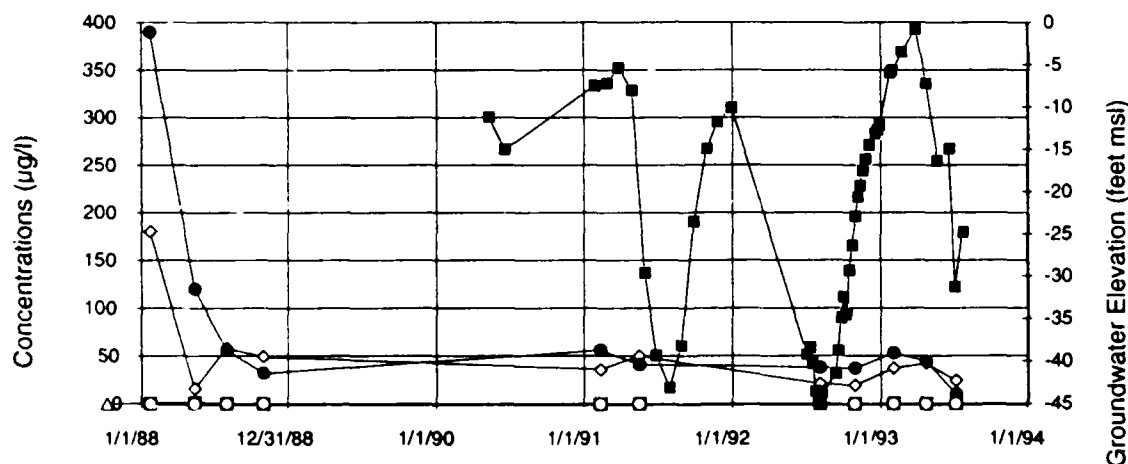
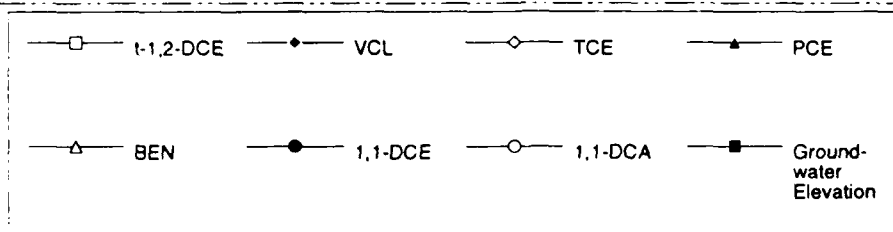


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FIGURE 4-6b
COC TIME CONCENTRATION
PLOT FOR MW-3
 DAVIS GLOBAL COMMUNICATIONS SITE
 McCLELLAN AIR FORCE BASE
 YOLO COUNTY, CALIFORNIA



SEE
INSERT



INSERT

FIGURE 4-6c
COC TIME CONCENTRATION
PLOT FOR MW-5
 DAVIS GLOBAL COMMUNICATIONS SITE
 MCCLELLAN AIR FORCE BASE
 YOLO COUNTY, CALIFORNIA

NOTE:

The following compounds were not detected:
1,1-DCA, BEN, VCL, t-1,2-DCE

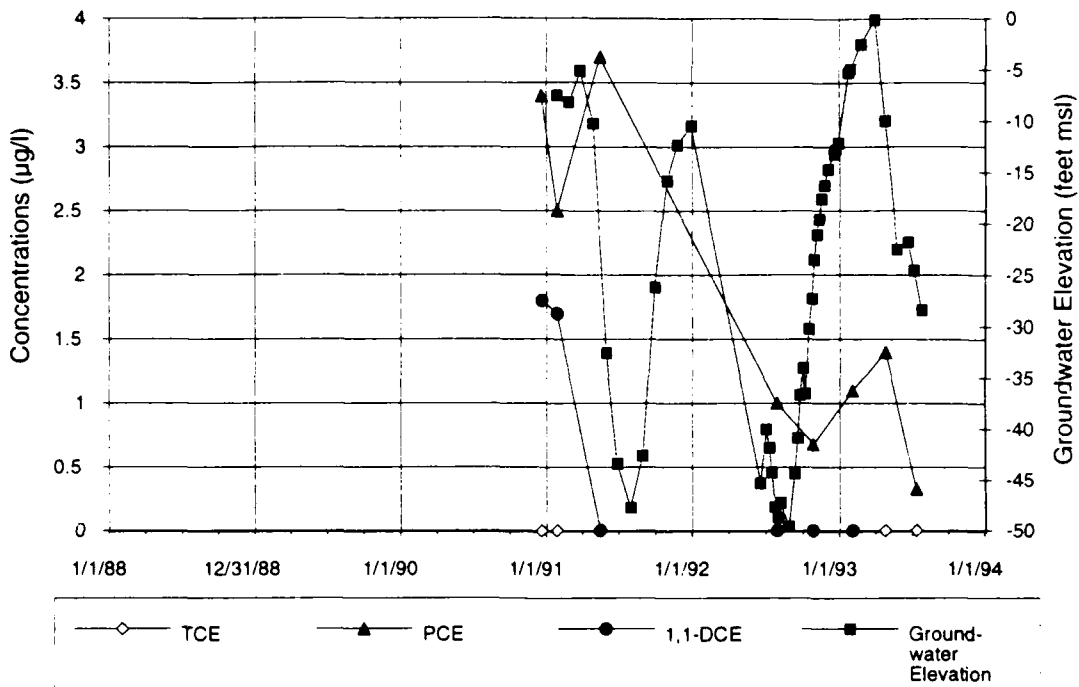


FIGURE 4-6d
COC TIME CONCENTRATION
PLOT FOR MWC-12
DAVIS GLOBAL COMMUNICATIONS SITE
McCLELLAN AIR FORCE BASE
YOLO COUNTY, CALIFORNIA

NOTE:

The following compounds were not detected:
1,1-DCA, BEN, VCL, t-1,2-DCE

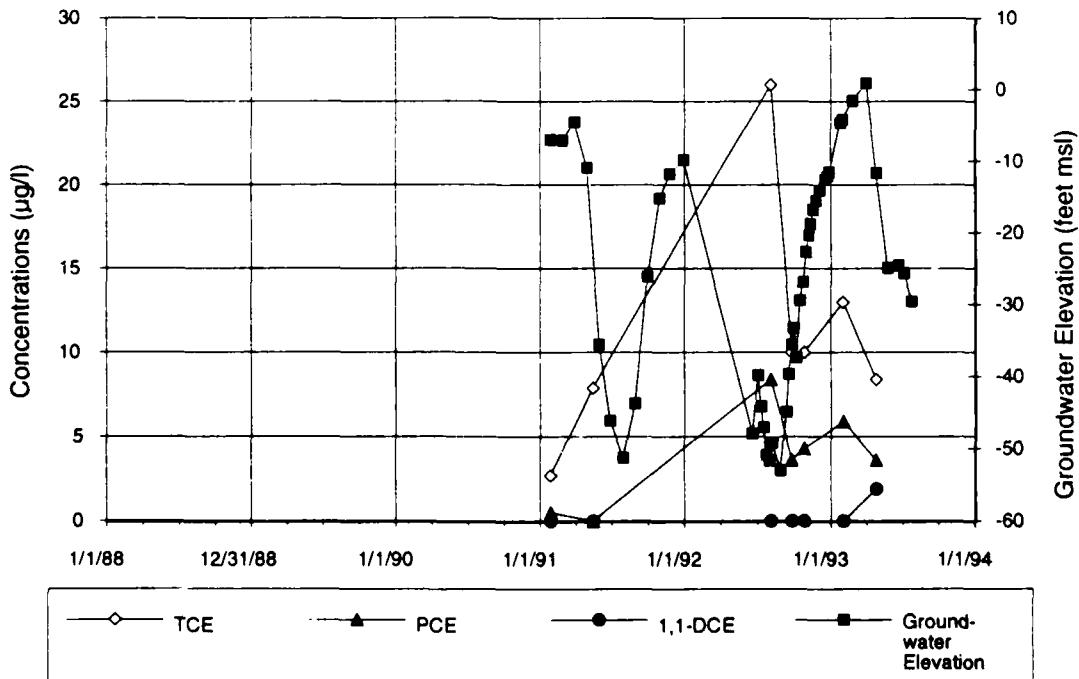


FIGURE 4-6e
COC TIME CONCENTRATION
PLOT FOR MWD-12
DAVIS GLOBAL COMMUNICATIONS SITE
McCLELLAN AIR FORCE BASE
YOLO COUNTY, CALIFORNIA

NOTE:

The following compounds were not detected:

1,1-DCA, BEN, VCL, t-1,2-DCE

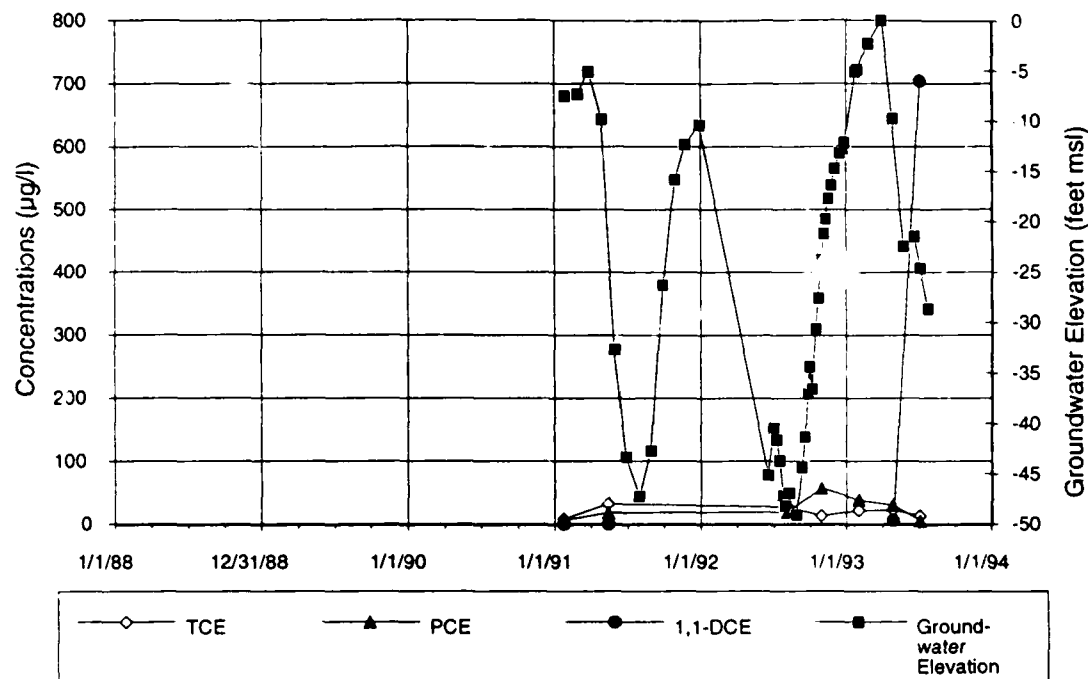


FIGURE 4-6f
COC TIME CONCENTRATION
PLOT FOR MWC-3

DAVIS GLOBAL COMMUNICATIONS SITE
McCLELLAN AIR FORCE BASE
YOLO COUNTY, CALIFORNIA

NOTE:

The following compounds were not detected:

BEN, VCL, t-1,2-DCE

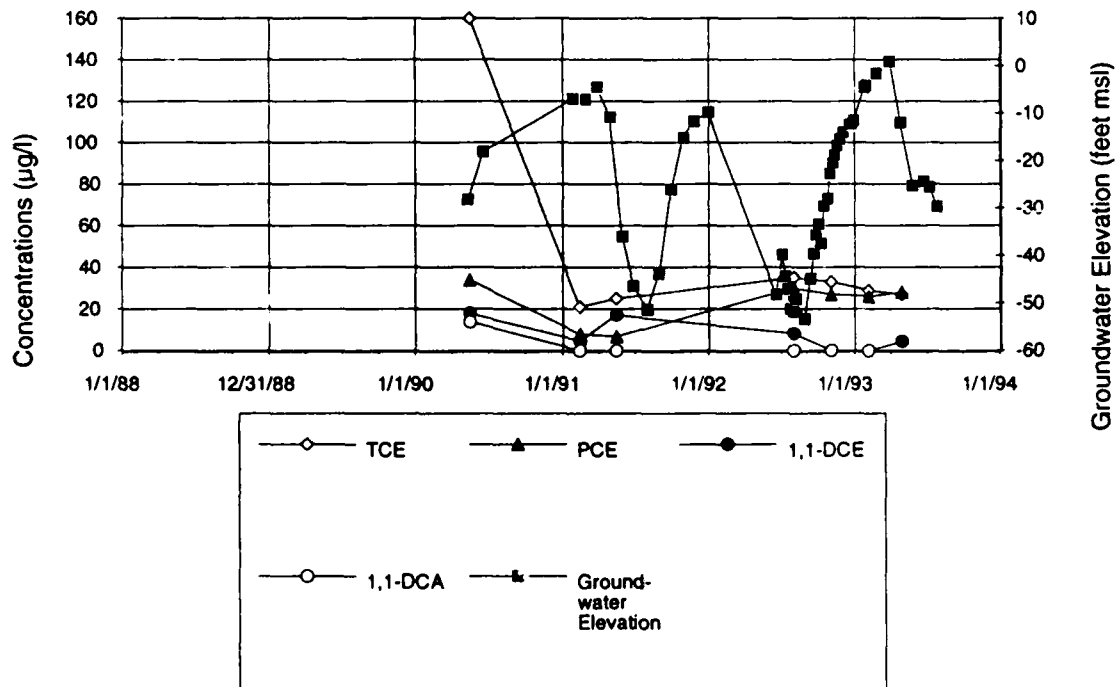


FIGURE 4-6g
COC TIME CONCENTRATION
PLOT FOR MWD-3

DAVIS GLOBAL COMMUNICATIONS SITE
McCLELLAN AIR FORCE BASE
YOLO COUNTY, CALIFORNIA

NOTE:

The following compounds were not detected:
1,1-DCA, BEN, VCL, t-1,2-DCE

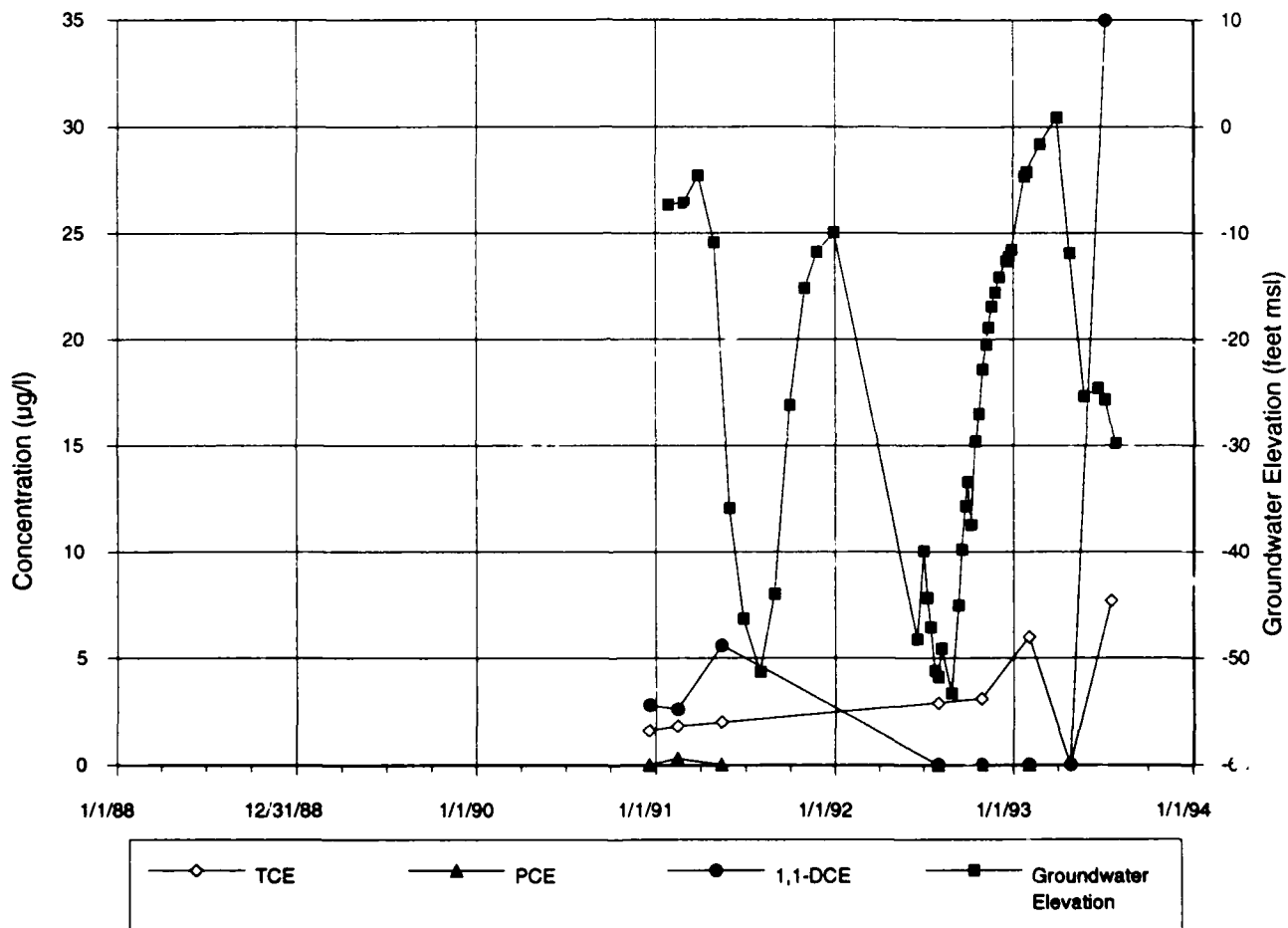


FIGURE 4-6h
COC TIME CONCENTRATION
PLOT FOR MWD-10
DAVIS GLOBAL COMMUNICATIONS SITE
MCLELLAN AIR FORCE BASE
YOLO COUNTY, CALIFORNIA

Table 4-8
Comparison of May 1988 and February 1993 Dissolved VOC Contamination

Compound	VOC Concentration (µg/l)							
	MW-1		MW-2		MW-3		MW-4	
	May 1988	Feb 1993	May 1988	Feb 1993	May 1988	Feb 1993	May 1988	Feb 1993
Tetrachloroethene	70.00	8.10	52.00	34.00	98.00	170.00	0.00	0.12
Trichloroethene	1,000.00	27.00	310.00	180.00	140.00	350.00	6.30	4.90
1,1-Dichloroethene	25.00	2.80	48.00	24.00	22.00	49.00	0.60	0.00
Vinyl Chloride	250.00	7.50	0.00	0.00	0.00	82.00	0.00	0.00
1,2-Dichloroethene	37.00	24.00	53.00	30.00	74.00	410.00	0.30	0.41
Total VOCs	1,382.00	69.40	463.00	268.00	334.00	1,061.00	7.20	5.43
Area	20,088	20,088	21,700	21,700	24,790	24,790	8,167	8,167
Porosity	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Saturated Thickness	45.00	50.00	45.00	50.00	45.00	50.00	45.00	50.00
VOC Mass (kg)	14.14	0.79	5.12	3.29	4.22	14.89	0.03	0.03
Total Mass (kg)	61.60	31.92						
Compound	MW-5		MW-6		MW-7		MW-8	
	May 1988	Feb 1993	May 1988	Feb 1993	May 1988	Feb 1993	May 1988	Feb 1993
Tetrachloroethene	1,400.00	350.00	1.90	1.60	14.00	6.70	0.30	0.33
Trichloroethene	16.00	37.00	12.00	6.70	63.00	70.00	20.00	16.00
1,1-Dichloroethene	120.00	53.00	0.00	0.00	29.00	7.00	10.00	2.70
Vinyl Chloride	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1,2-Dichloroethene	1.50	0.00	0.00	0.00	18.00	24.00	5.50	2.60
Total VOCs	1,537.50	440.00	13.90	8.30	124.00	107.70	35.80	21.63
Area	46,805	46,805	14,222	14,222	16,722	16,722	15,167	15,167
Porosity	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Saturated Thickness	45.00	50.00	45.00	50.00	45.00	50.00	45.00	50.00
VOC Mass (kg)	36.66	11.66	0.10	0.07	1.06	1.02	0.28	0.19
Total Mass (kg)								

groundwater outward and downward from the groundwater source area around Wells MW-2 and MW-3.

4.3.5 Natural Biological Attenuation Potential

The groundwater quality data were reviewed for evaluation of natural biological attenuation of VOCs. A detailed discussion of this evaluation is presented in Appendix N. The data were analyzed for significant changes in concentrations over time that might be caused by biotransformation. The analyses indicate that insufficient data are available for a thorough evaluation, but the following conclusions were derived:

- Biotransformation in the form of anaerobic dehalogenation may be occurring in the vicinity of soil gas Monitoring Well CH-5. This process may be a source of vinyl chloride to the groundwater in the B aquifer.
- It is unlikely that a significant portion of the decreases shown by the concentration versus time plots can be accounted for by aerobic transformation.

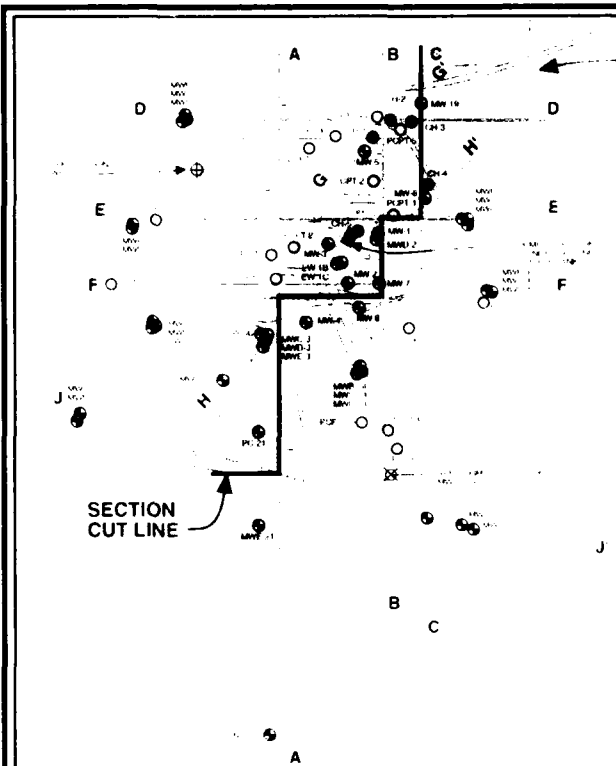
Further sampling for byproducts of anaerobic dehalogenation (ethene and ethane in the soil gas and in the groundwater) will help determine if vinyl chloride is being dehalogenated to less hazardous compounds. Measurement of O_2 , CO_2 , CH_4 , and H in the soil gas would also help determine the natural biological processes occurring in this area. However, soil gas sampling should be coordinated with the ongoing bioventing study to determine the effects of increased oxygen in the subsurface.

4.3.6 Conceptual Model Development

Figure 4-7 shows the conceptual model for the site. The conceptual model is viewed as the end product of the data interpretation for the site. The conceptual model shows potential and probable contaminant pathways throughout the subsurface of the Davis Site. It is a schematic representation of the existing VOC and petroleum hydrocarbon contaminant mass. The hydrogeologic interpretation for the conceptual model was based on data presented in the site cross sections (Figures 4-7 through 4-17) found at the end of the chapter.

The conceptual model illustrates the presence of vadose zone contamination near the northeast boundary of the fenced compound and near Soil Vapor Monitoring Well CH-5. It also illustrates the shallow groundwater contaminant mass concentrated in the thickest portion of the B aquifer near EW-1B and how that contamination has spread downward and outward from this B aquifer source area to the C, D, and E aquifers.

The total contaminant mass beneath the site is an uncertain quantity. Estimates of the total mass were based on measured values and published references. While an accurate estimate of the contaminant mass is important, the distribution and movement of contamination will dictate remedial actions. The conceptual model illustrates the most important concern—contaminant movement into the regional aquifers.



SITE PLAN

Predominant flow direction
of depositional channel

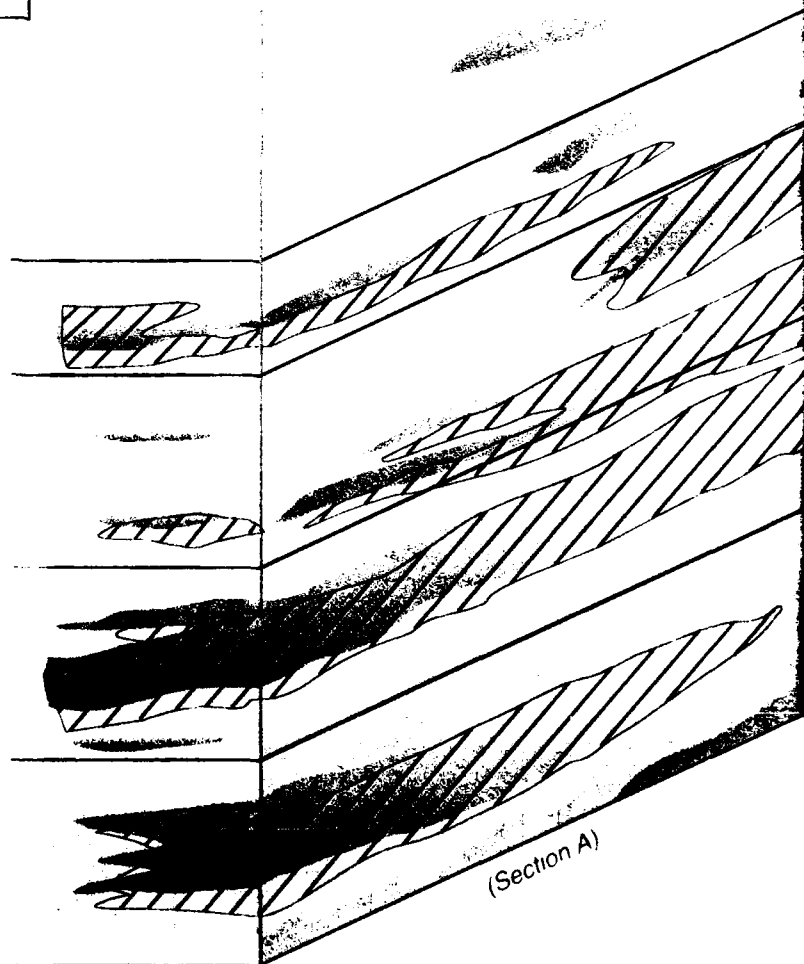
Vadoze
Zone

B
Zone

C
Zone

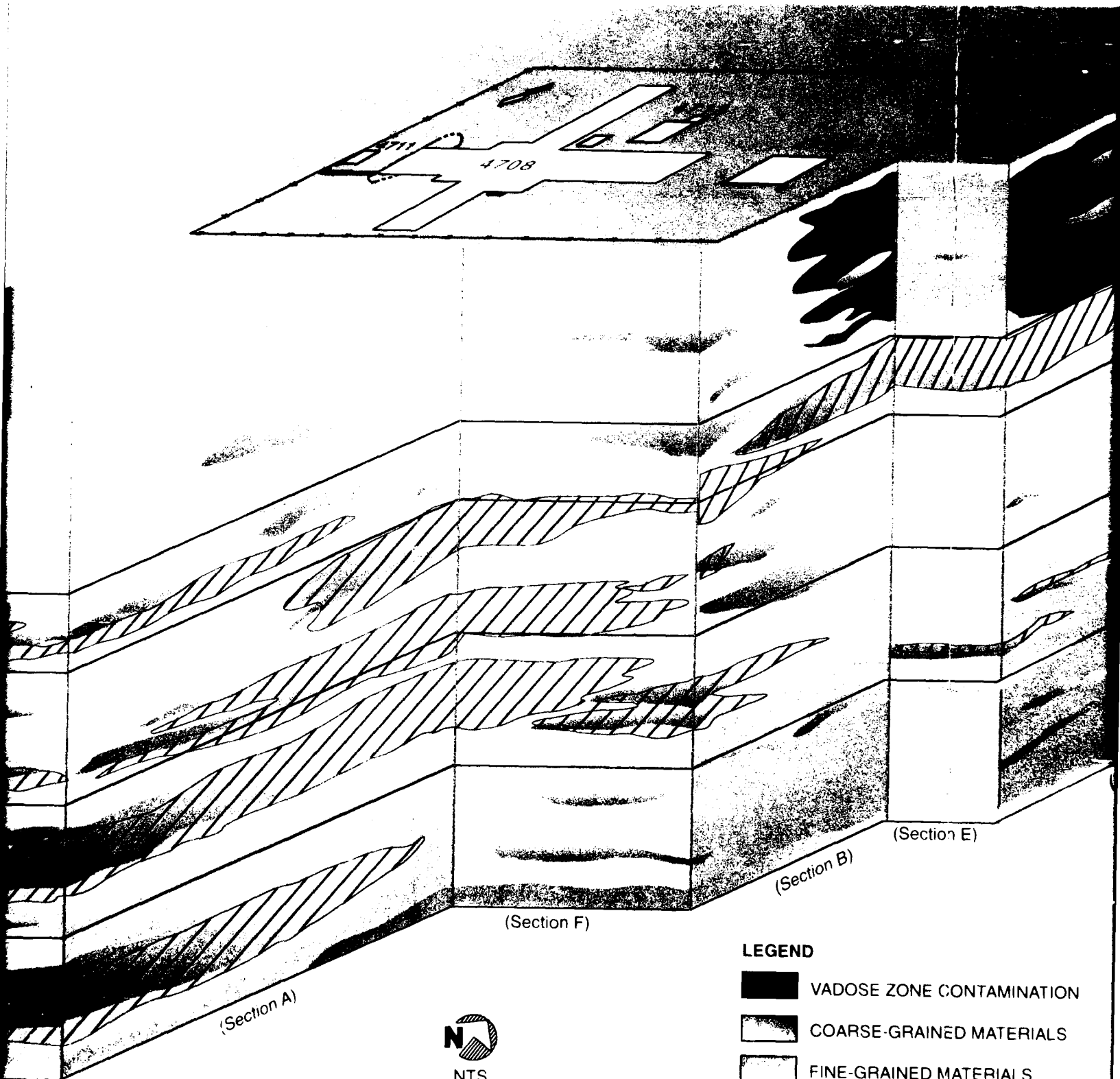
D
Zone

E
Zone








VERTICAL E
(Approximate)

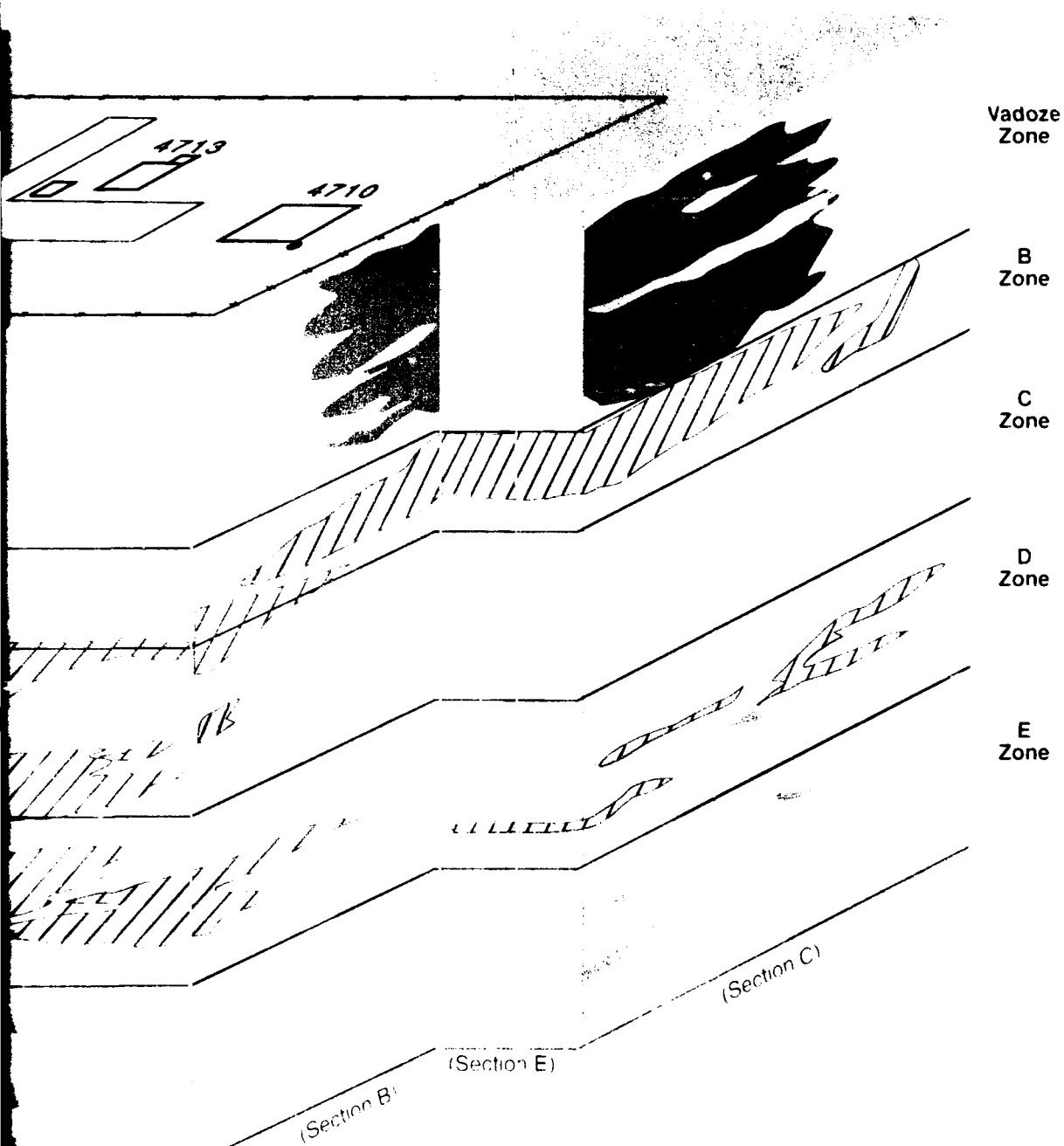
nt flow direction
nal channel



VERTICAL EXAGGERATION 2.1
(Approximate)

LEGEND

-  VADOSE ZONE CONTAMINATION
-  COARSE-GRAINED MATERIALS
-  FINE-GRAINED MATERIALS
-  VOC CONTAMINATION
-  VOC TRANSPORT THROUGH COARSE-GRAINED MATERIALS

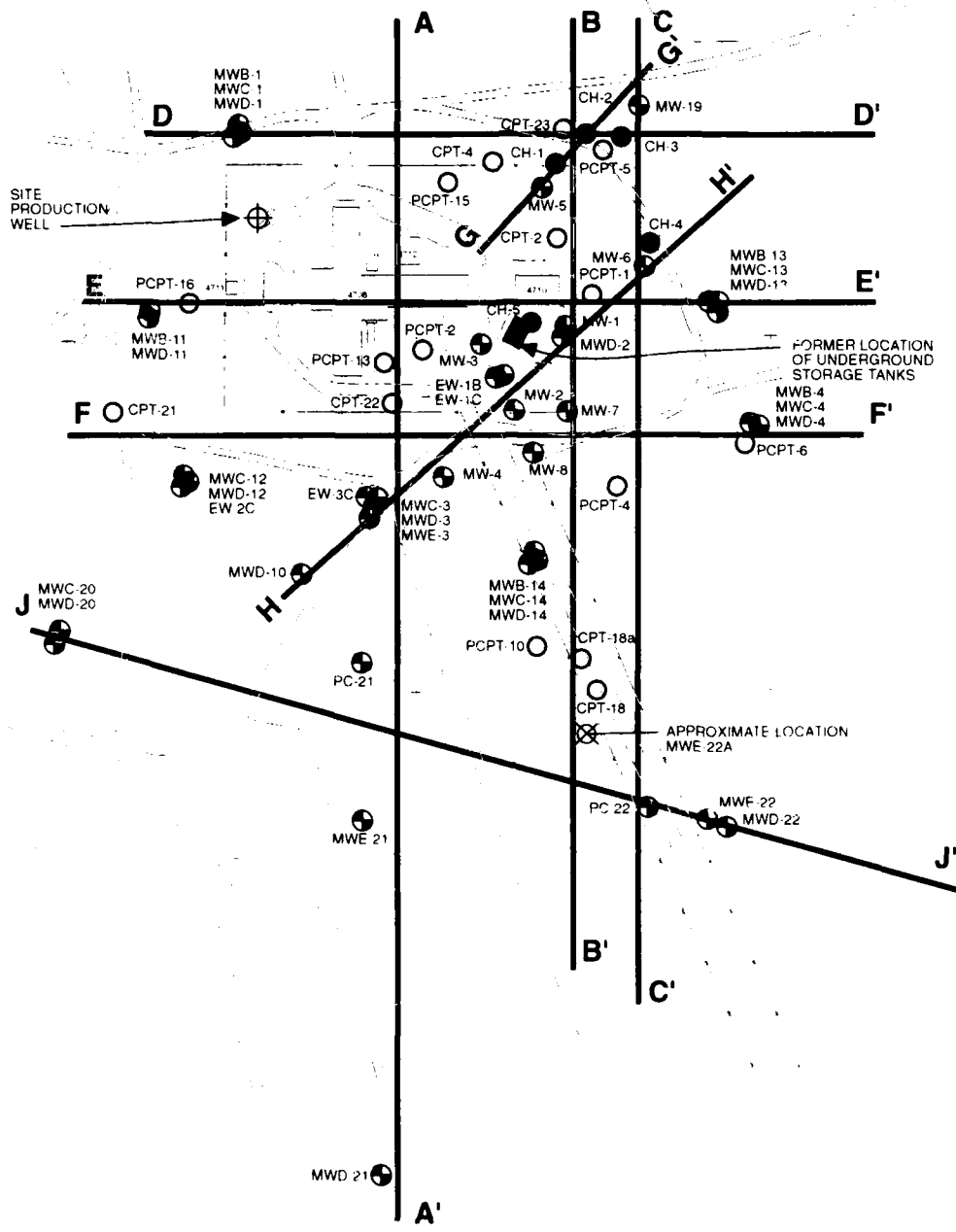


LEGEND

- VADOSE ZONE CONTAMINATION
- COARSE GRAINED MATERIALS
- FINE GRAINED MATERIALS
- VOC CONTAMINATION
- VOC TRANSPORT THROUGH COARSE GRAINED MATERIALS

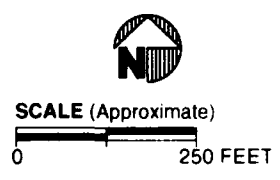
FIGURE 4-7 DAVIS SITE CONCEPTUAL MODEL

DAVIS GLOBAL COMMUNICATIONS SITE
MCLELLAN AIR FORCE BASE
YOLO COUNTY, CALIFORNIA



LEGEND

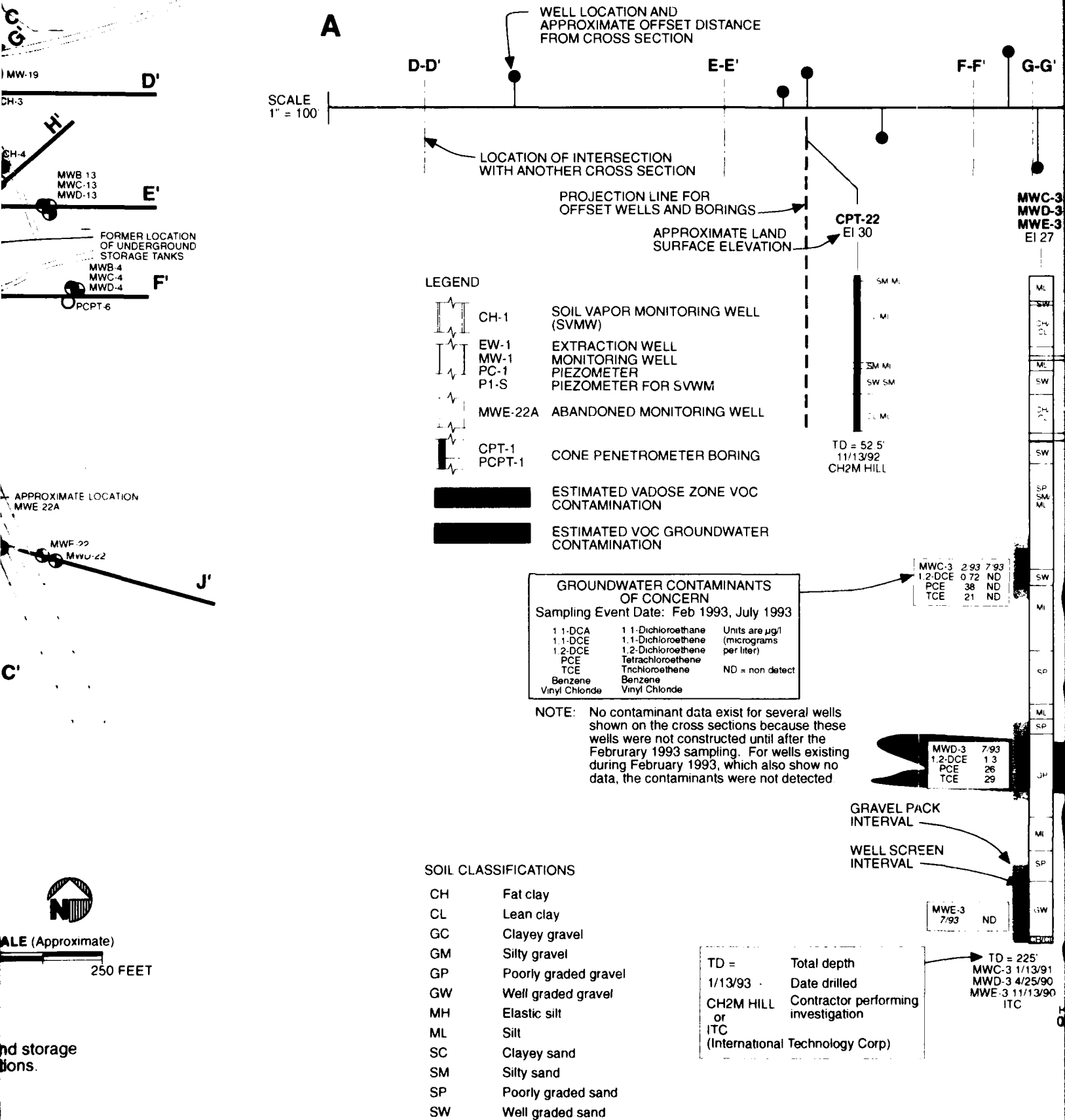
- ⊕ GROUNDWATER MONITORING WELL
- SOIL VAPOR MONITORING WELL
- CONE PENETROMETER BORING
- ⊗ ABANDONED BOREHOLE



SITE MAP

Showing cross section locations, former underground storage tank location, and various monitoring well locations.

CROSS SECTION PLAN VIEW



CROSS SECTION PLAN VIEW

LOCATION AND
APPROXIMATE OFFSET DISTANCE
CROSS SECTION

E-E'

F-F'

G-G'

A'

E

W

S

INTERSECTION
CROSS SECTION

DIRECTION LINE FOR
OFFSET WELLS AND BORINGS

APPROXIMATE LAND
SURFACE ELEVATION

CPT-22
EI 30

MWC-3
MWD-3
MWE-3
EI 27

SOIL GAS
ANALYTICAL
RESULTS
Dates of sampling
12/92 and 7/93
PCE
TCE (ppbv)

CH-2
P-2M
EI 26

VAPOR MONITORING WELL
(VW)

REACTION WELL
MONITORING WELL
COMETER
COMETER FOR SVWM

UNDONED MONITORING WELL

IE PENETROMETER BORING

IMATED VAPOUR ZONE VOC
ITAMINATION

IMATED VOC GROUNDWATER
ITAMINATION

GROUNDWATER CONTAMINANTS
OF CONCERN

ing Event Date: Feb 1993, July 1993

CA	1,1-Dichloroethane	Units are µg/l
CE	1,1-Dichloroethane	(microgram
CE	1,2-Dichloroethane	per liter)
	Tetrachloroethane	
	Trichloroethane	ND = non detect
	Benzene	
	Vinyl Chloride	

No contaminant data exist for several wells
shown on the cross sections because these
wells were not constructed until after the
February 1993 sampling. For wells existing
during February 1993, which also show no
data, the contaminants were not detected

MWC-3	2/93	7/93
1,2-DCE	0.72	ND
PCE	38	ND
TCE	21	ND

MWC-3
3/93
EI 0.02

MWD-3
3/93
EI 1.14

MWC-3
7/93
EI 24.6

MWD-3
7/93
EI 27.6

WELL NUMBER
DATE MEASURED
GROUNDWATER ELEVATION
(feet mean sea level)

TD = 41.5
11/23/92
CH2M HILL

GEOPHYSICAL
LOG

MWD-3 7/93
1,2-DCE 1.3
PCE 26
TCE 29

GRAVEL PACK
INTERVAL

WELL SCREEN
INTERVAL

MWE-3
7/93
ND

DIRECTION OF
CONTAMINANT
MOVEMENT

ELOG SCALE

16-INCH NORMAL
RESISTIVITY/OHMS

TD = Total depth
1/13/93 Date drilled
CH2M HILL Contractor performing
or ITC investigation
(International Technology Corp)

TD = 225'
MWC-3 1/13/91
MWD-3 4/25/90
MWE-3 11/13/90
ITC

FIGURE 4-8
CROSS SECTION
LOCATIONS AND LEGEND
DAVIS GLOBAL COMMUNICATIONS SITE
McCLELLAN AIR FORCE BASE
YOLO COUNTY, CALIFORNIA

CH2M HILL

SCALE
1" = 100'

E-E'

$$H-H'$$
DEPTH
(FT)PCPT-15
E1 28PCPT-2
EI 28

CPT-22
EI 30

MW
El 2

MWC-3
MWD-3
MWE-3
EI 27

4

40

80

120

160

330

340

290

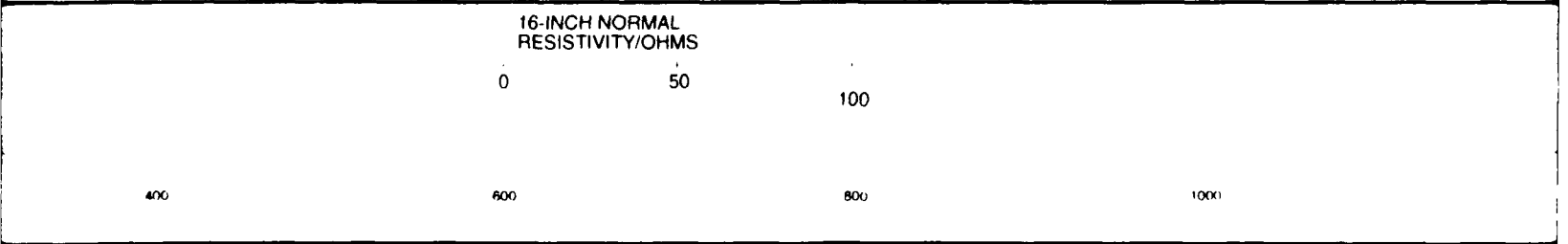
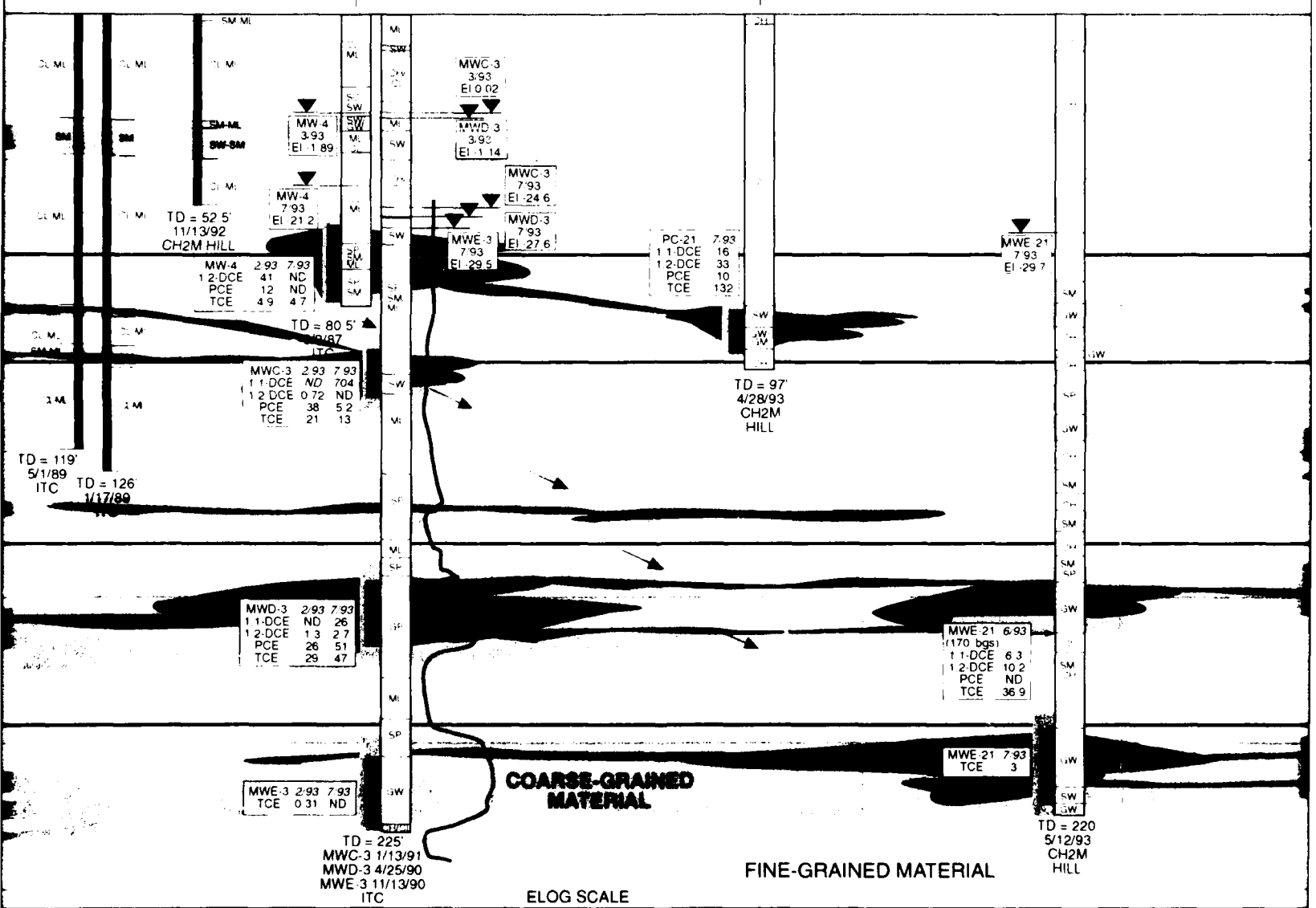
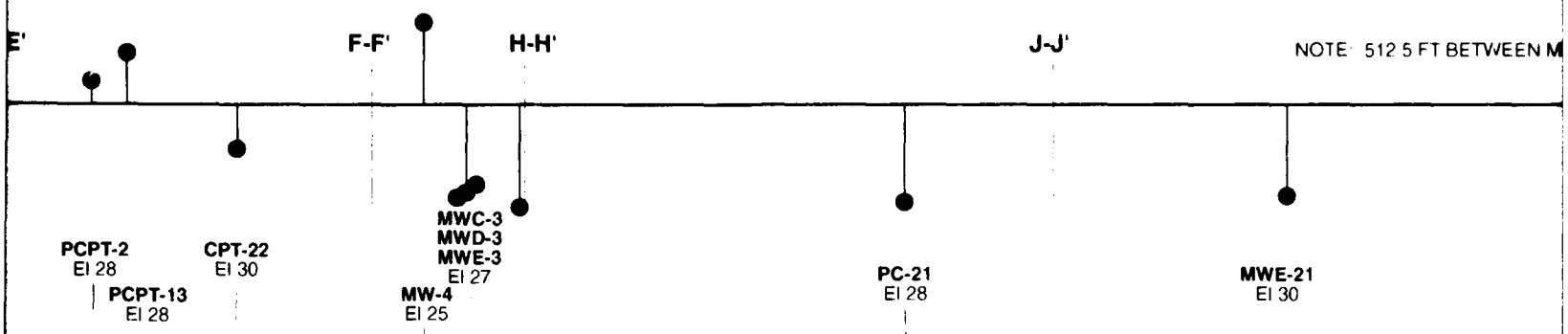
SITE PLAN

RDD1412_101

16-INCH NOMINAL
RESISTIVITY

0

600



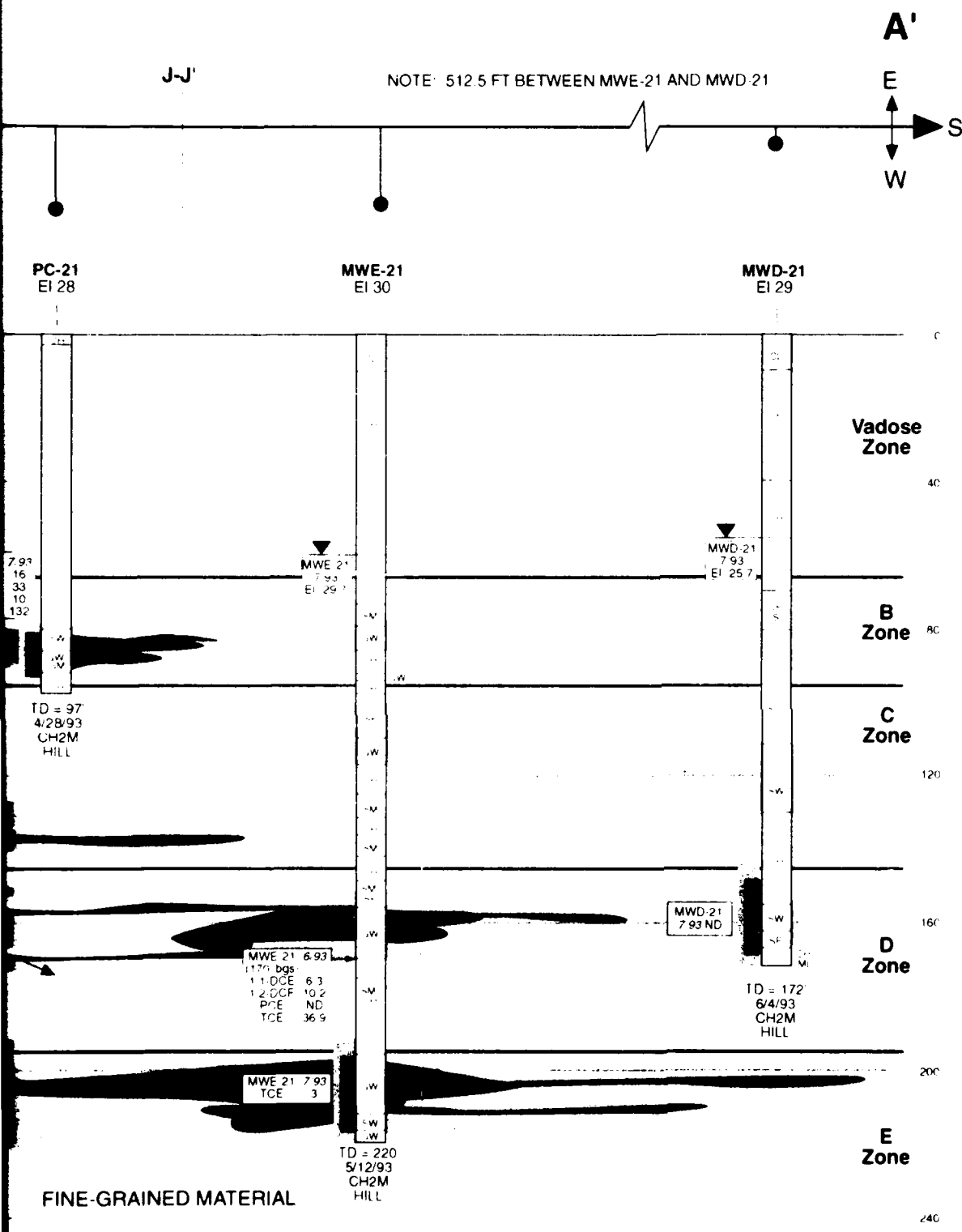
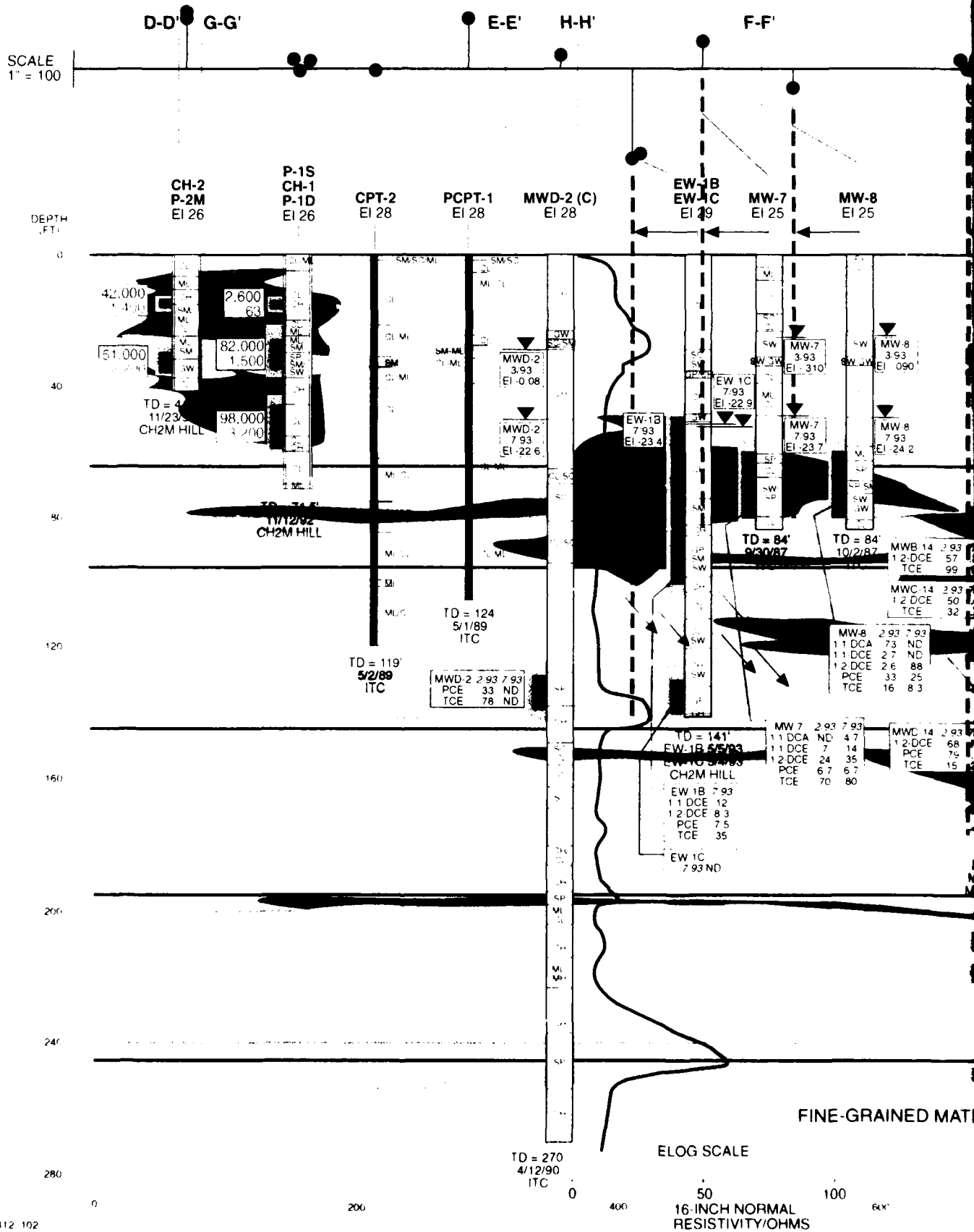
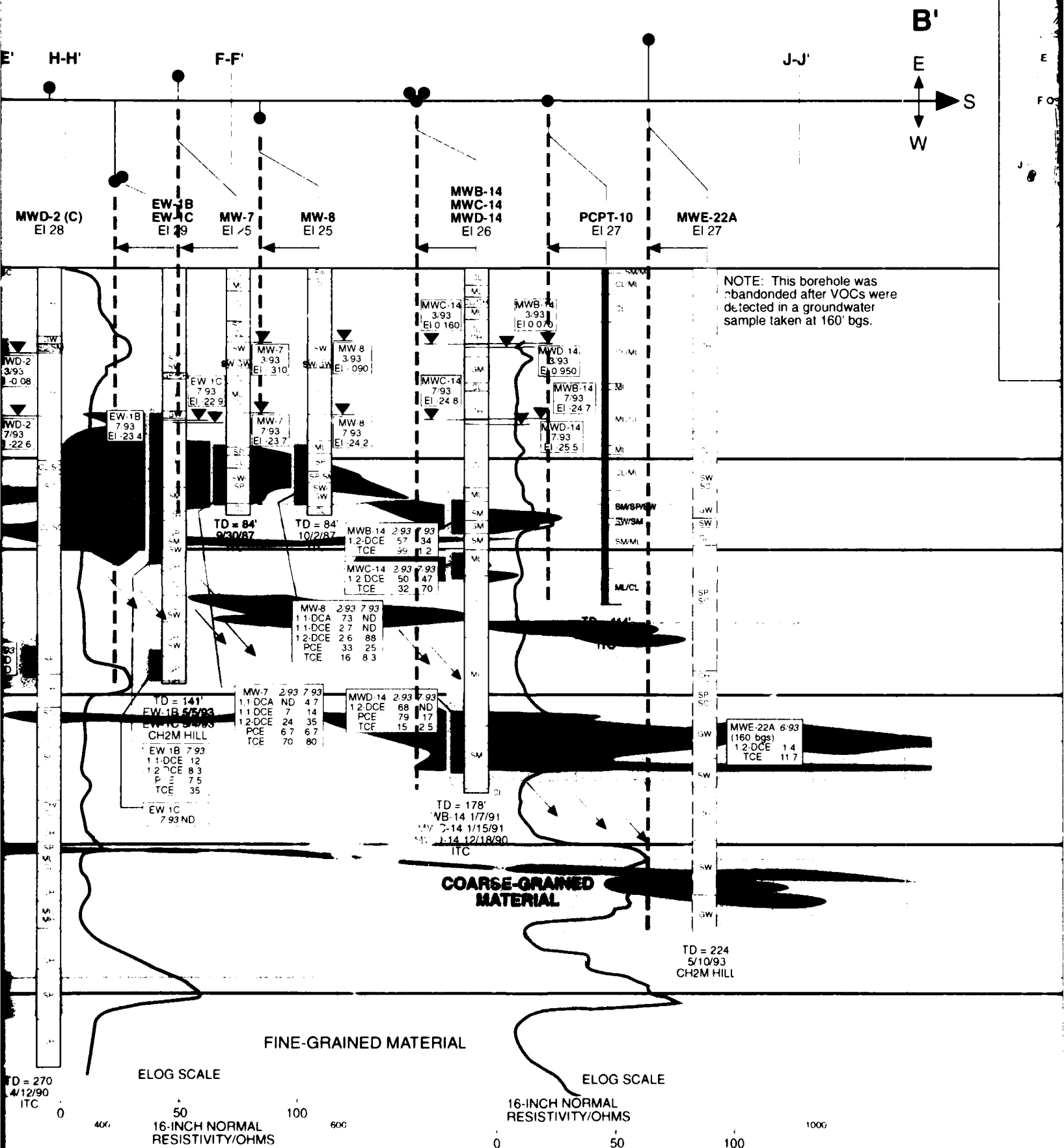
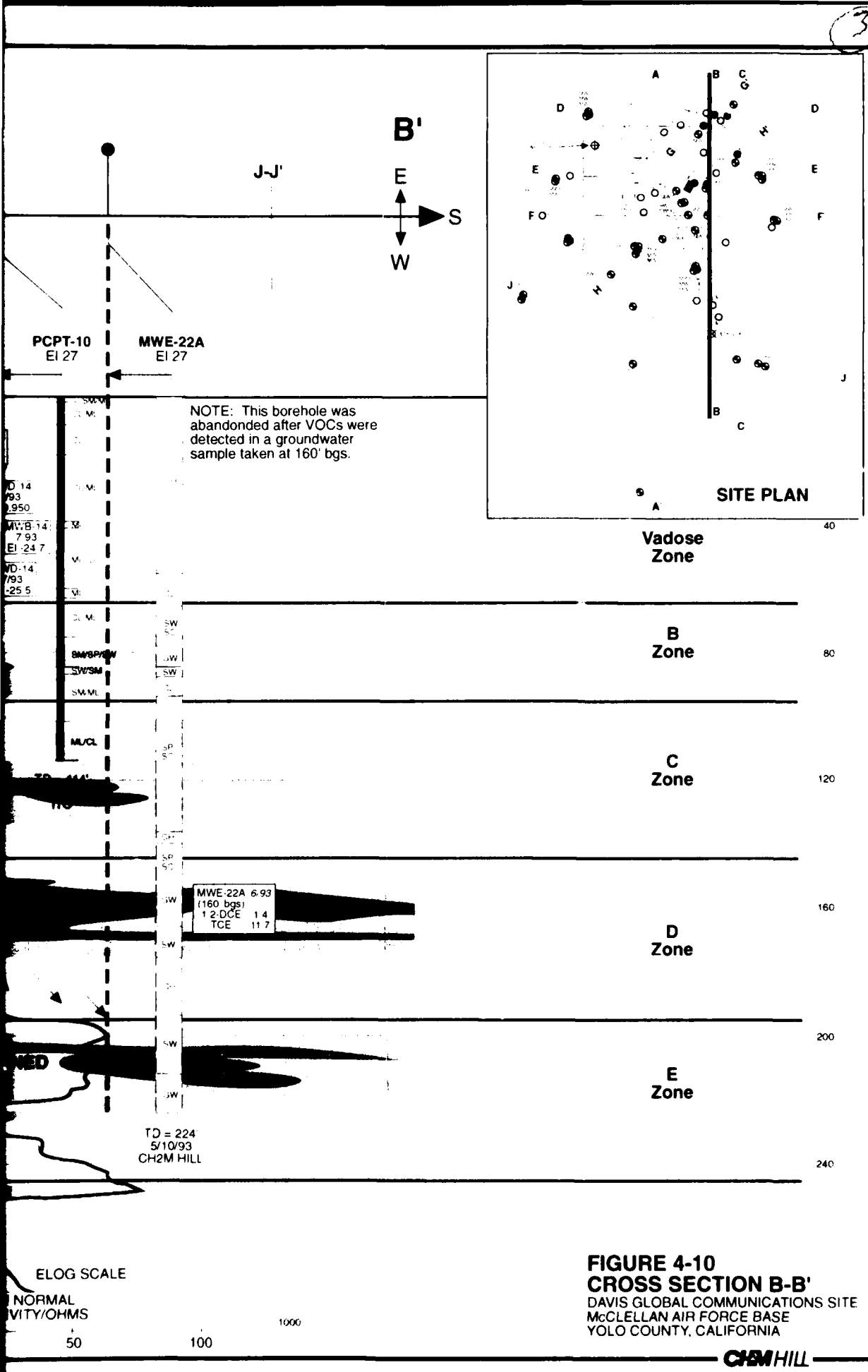


FIGURE 4-9
CROSS SECTION A-A'
DAVIS GLOBAL COMMUNICATIONS SITE
McCLELLAN AIR FORCE BASE
YOLO COUNTY, CALIFORNIA

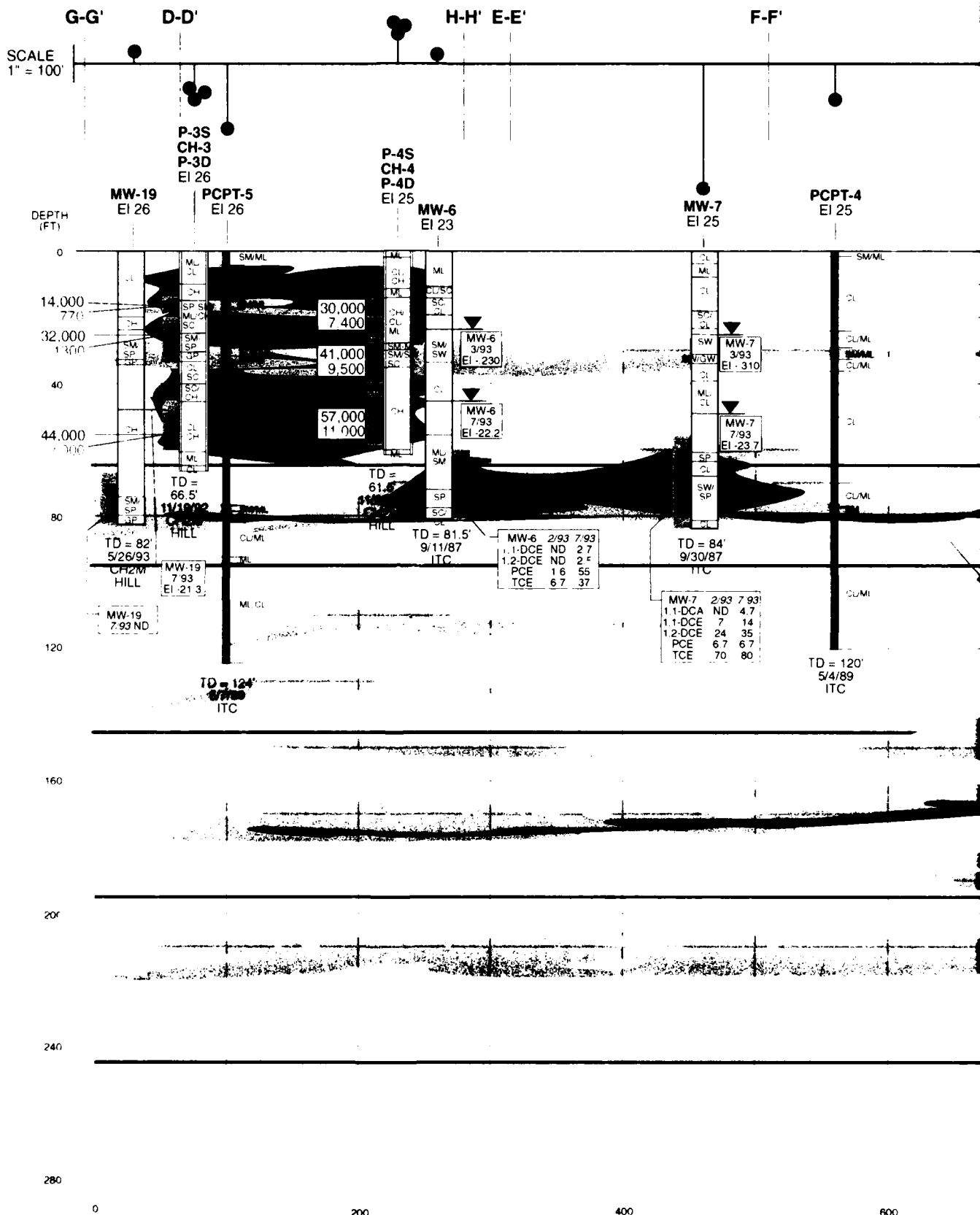
B

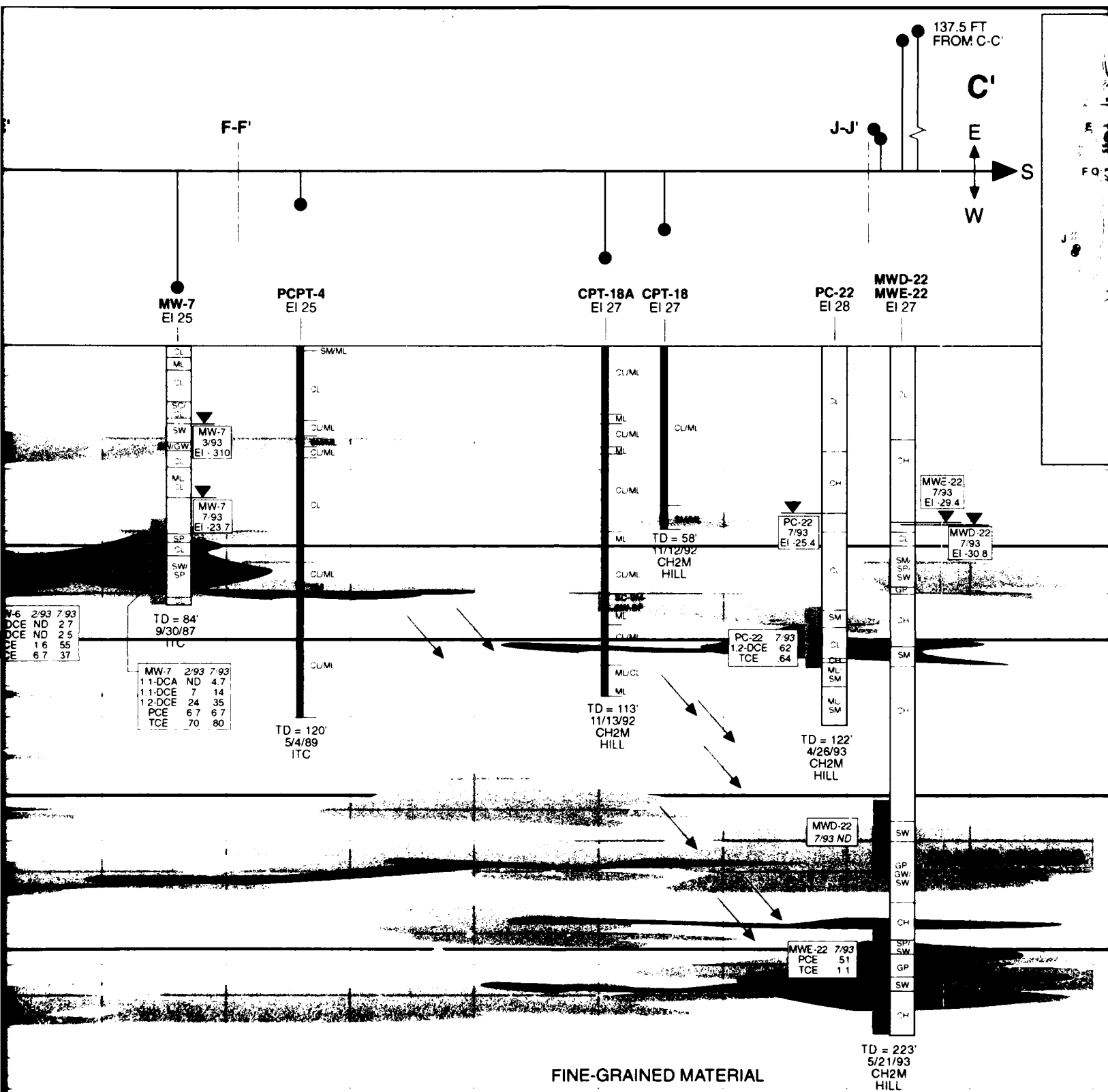






C





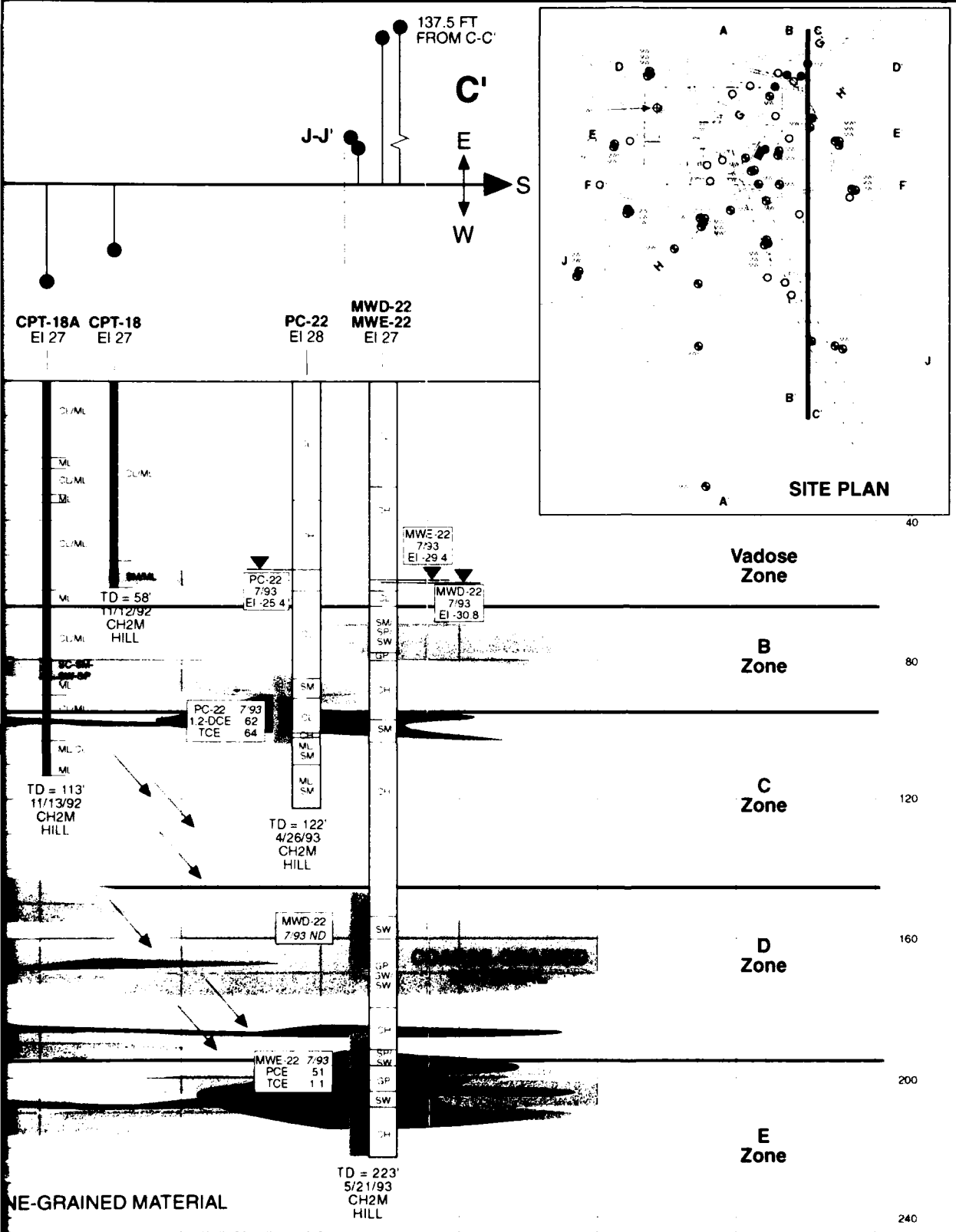


FIGURE 4-11
CROSS SECTION C-C'
 DAVIS GLOBAL COMMUNICATIONS SITE
 MCCLELLAN AIR FORCE BASE
 YOLO COUNTY, CALIFORNIA

CH2M HILL

B-B' G-G'

DEPTH
(FT)

MWB-1
MWC-1
MWD-1
EI 30

PCPT-15
EI 28

CPT-4
EI 28

P-1S
CH-1
P-1D
EI 26

CH-2
P-2M
EI 26

2

40

80

120

160

200

240

280

MWB-1	2/93	7/93
PCE	1.7	1.2
TCE	0.58	ND

MWC-1	2/93	7/93
TCE	ND	0.57

MWD-1	2'93	7'93
	ND	ND

TD = 240'
MWB-1 11/1/90
MWC-1 11/5/90
MWD-1 4/3/90
ITC

ELOG SCALE

16-INCH NORMAL
RESISTIVITY/OHMS

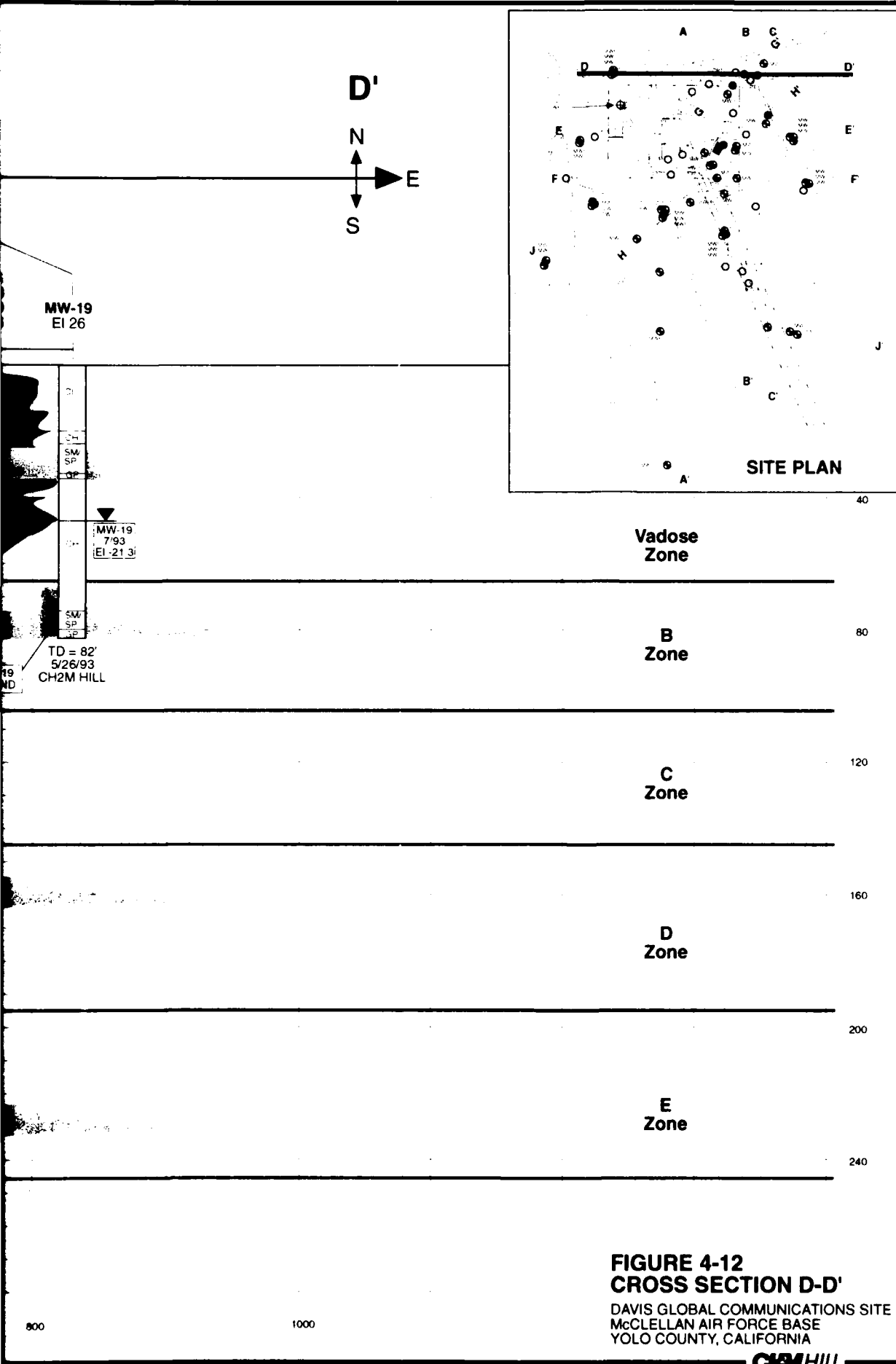
TD = 145'
1/18/90
ITC

TD = 119
5/8/89
ITC

42,000	CU
1,400	ML
2,600	CL
63	CH
32,000	CU/M
1,500	MU/S
	SP/S
	/SW
	CH
98,000	CL
3,200	CL
	CL

CH2M
HILL

FINE-GRAINED MATERIAL

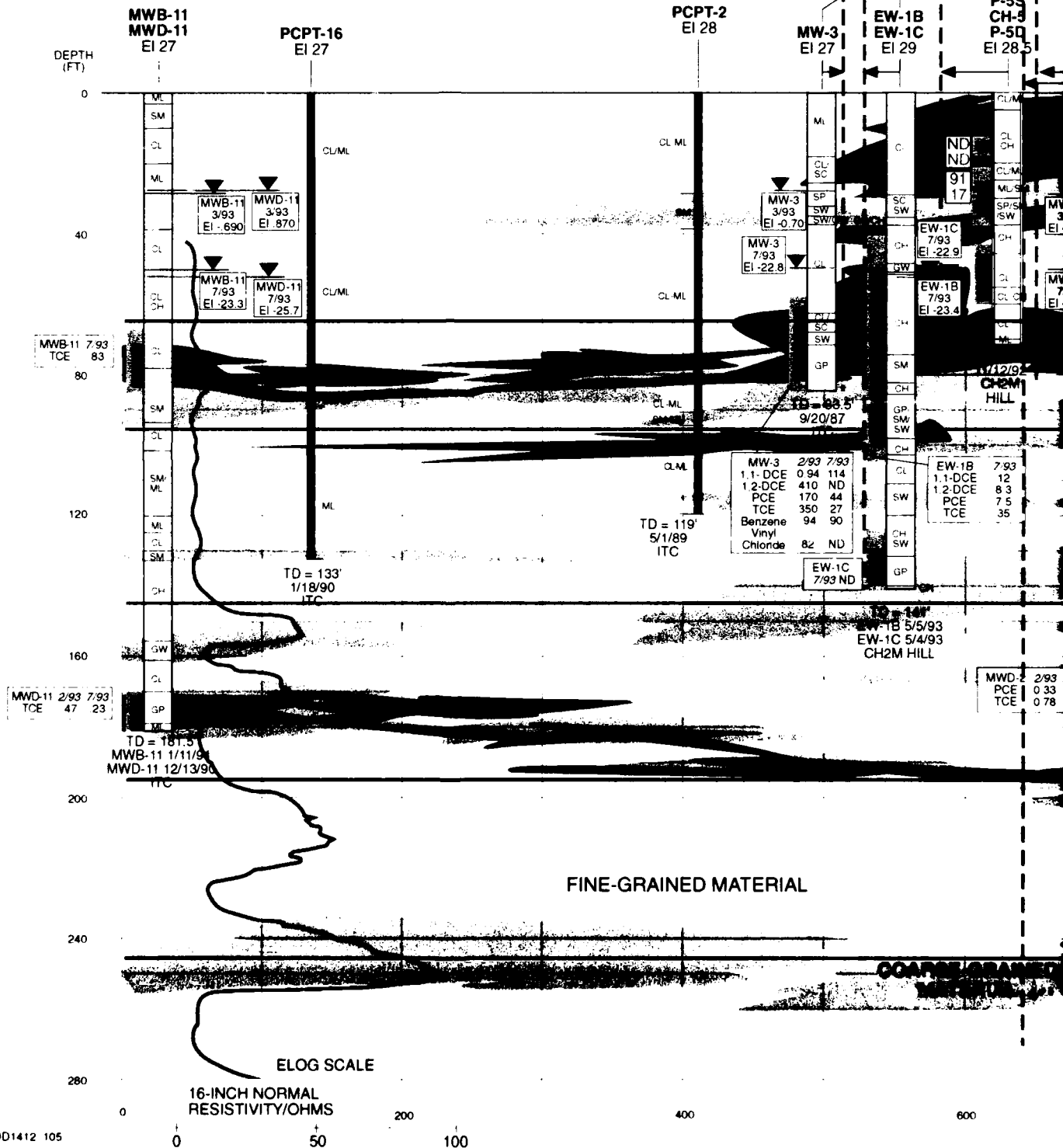


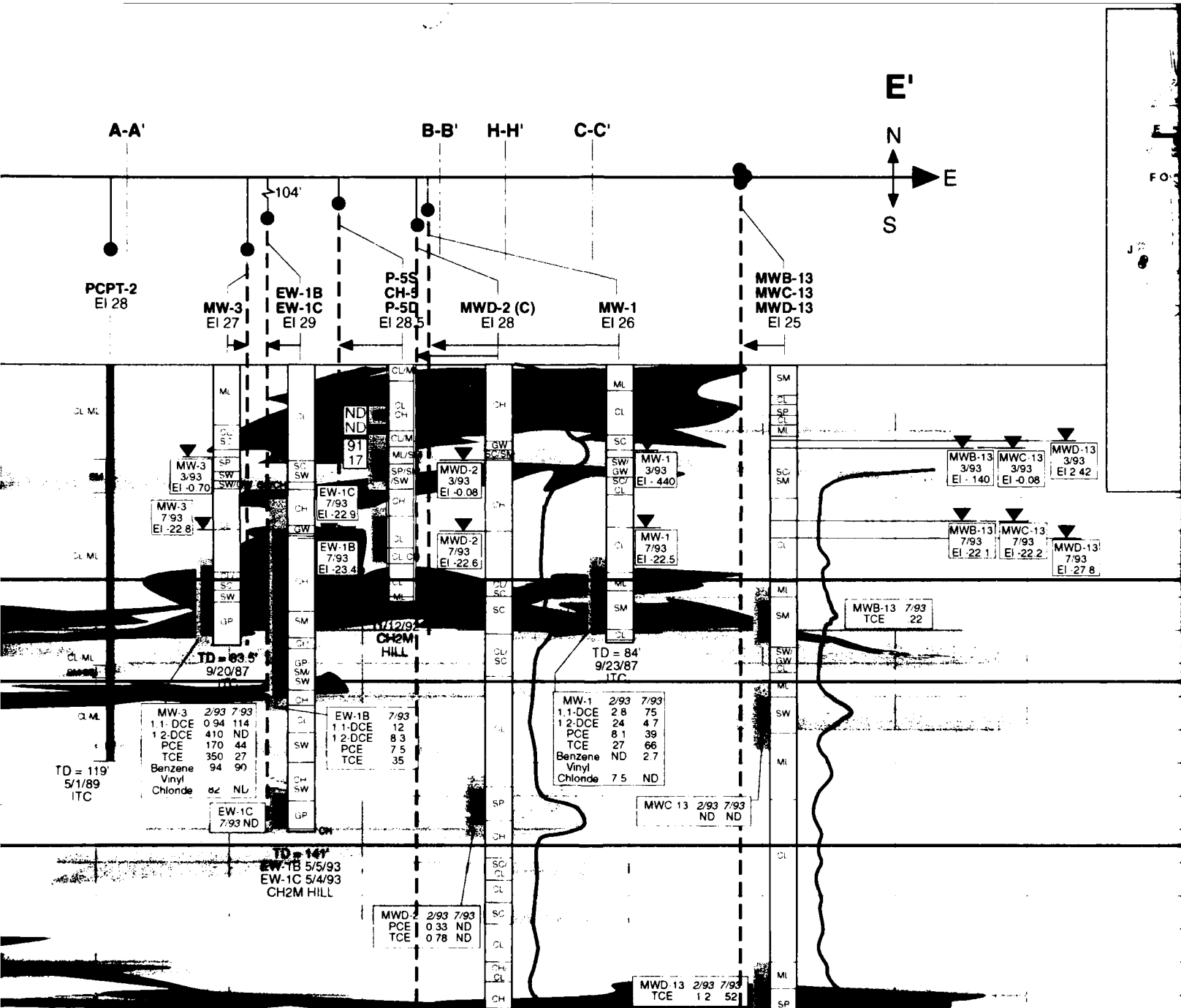
E

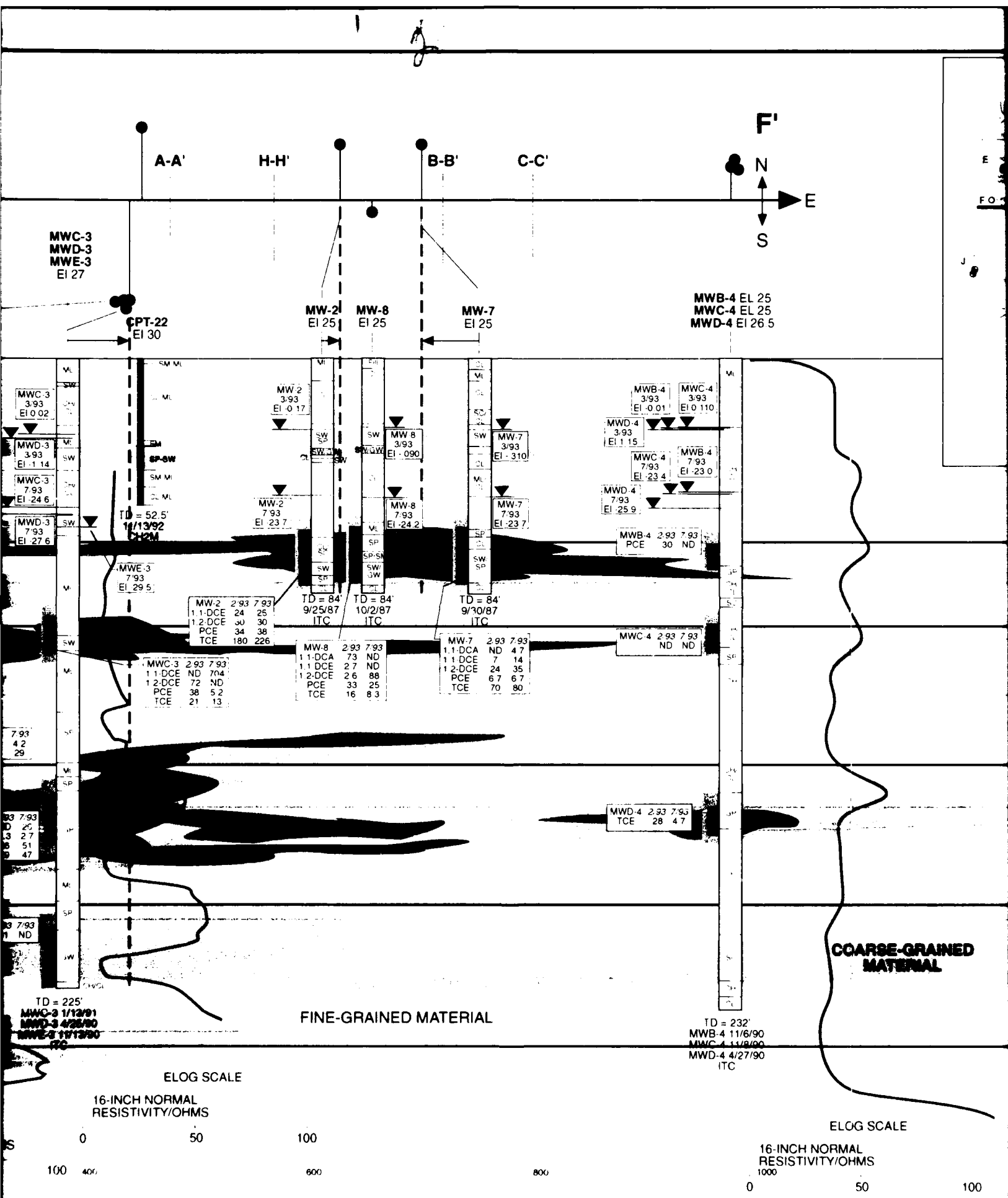
A-A'

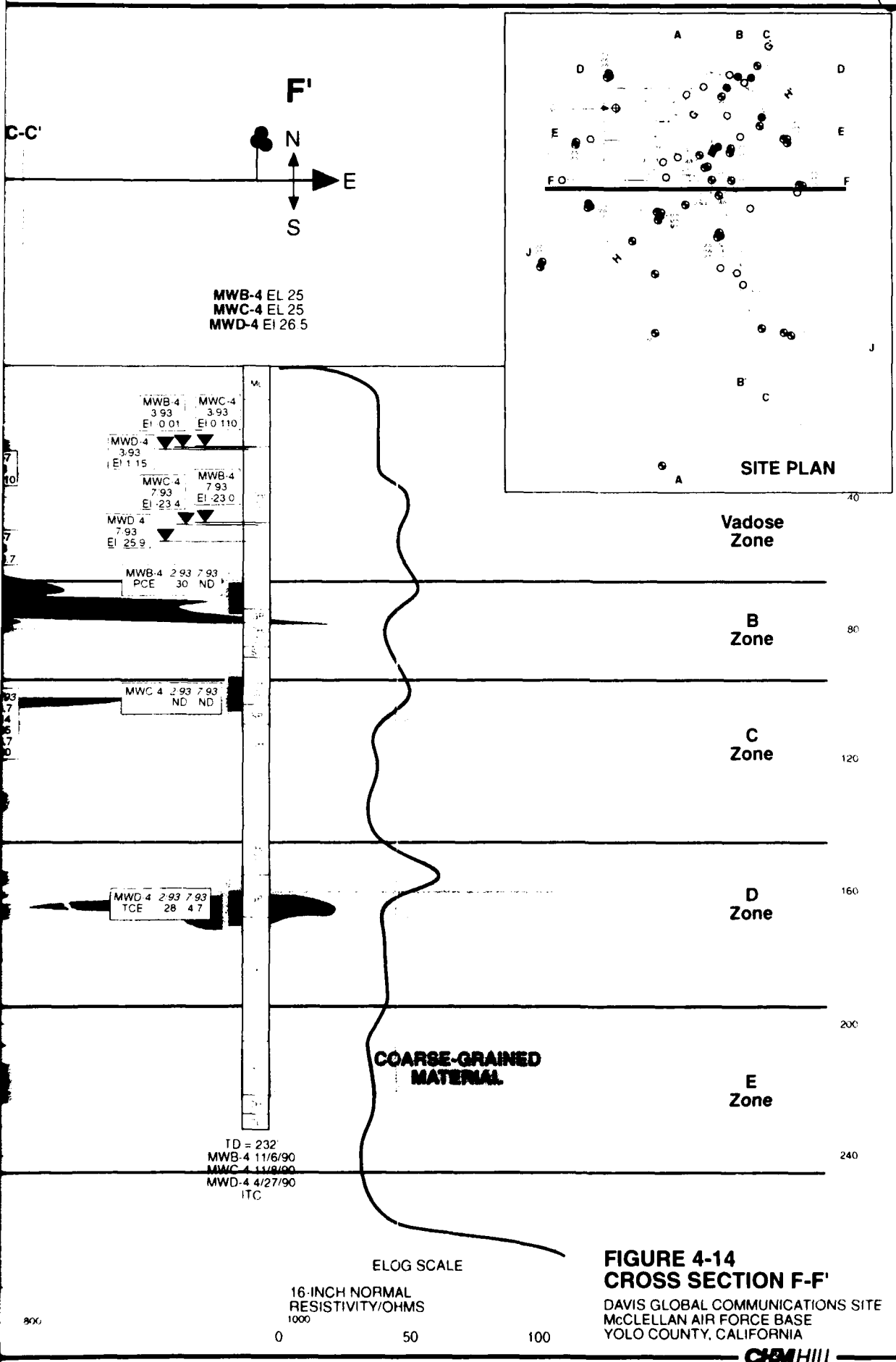
B-B'

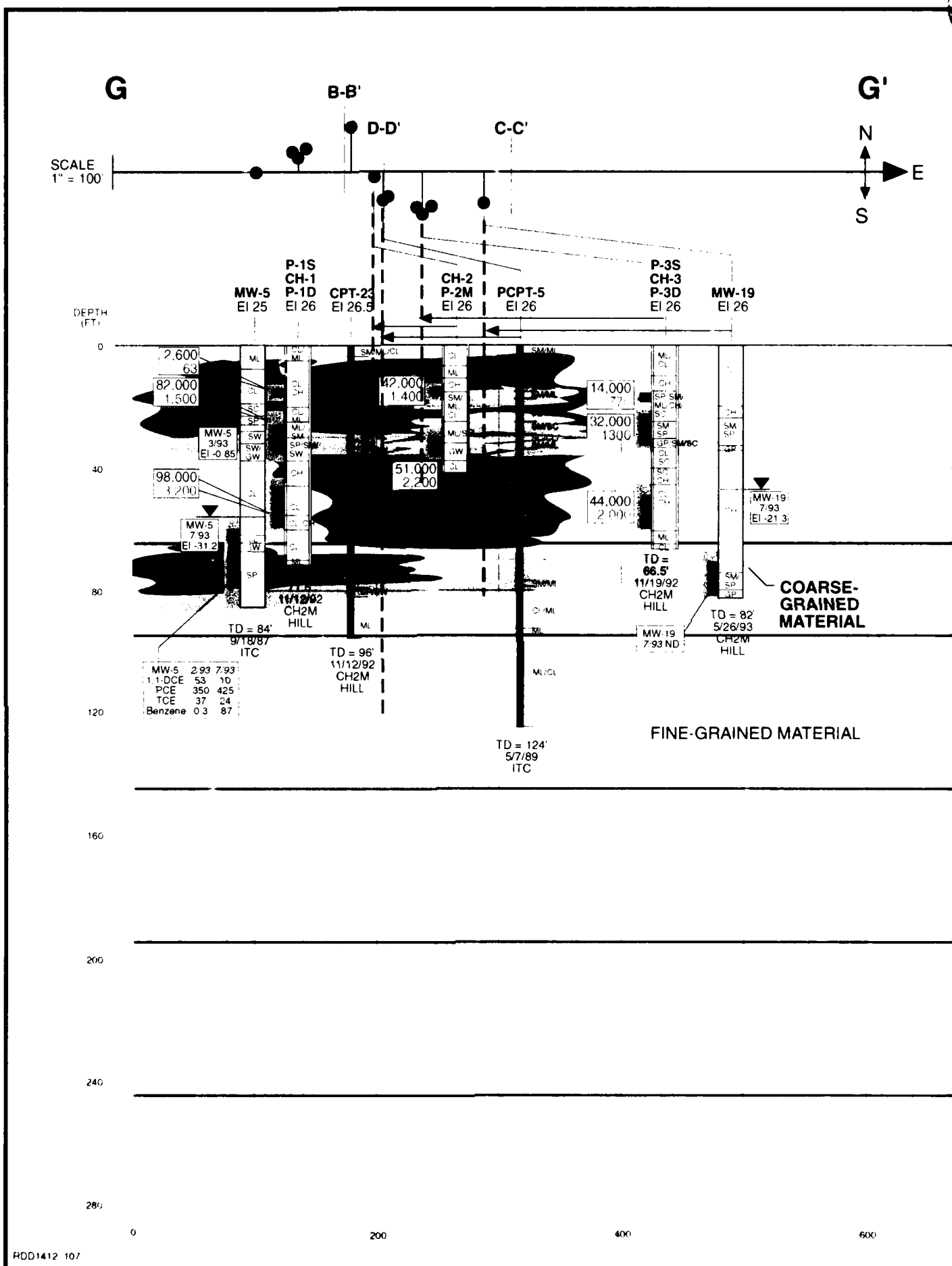
SCALE
1" = 100'











G'

N

S

E

P-3S
CH-3
P-3D
EI 26

MW-19
EI 26

14,000

32,000

1300

44,000

2,000

TD =
68.5'
11/19/92
CH2M
HILL

MW-19
7-93 ND

TD = 82'
5/26/93
CH2M
HILL

MW-19
7-93
EI -21.3

COARSE-
GRAINED
MATERIAL

FINE-GRAINED MATERIAL

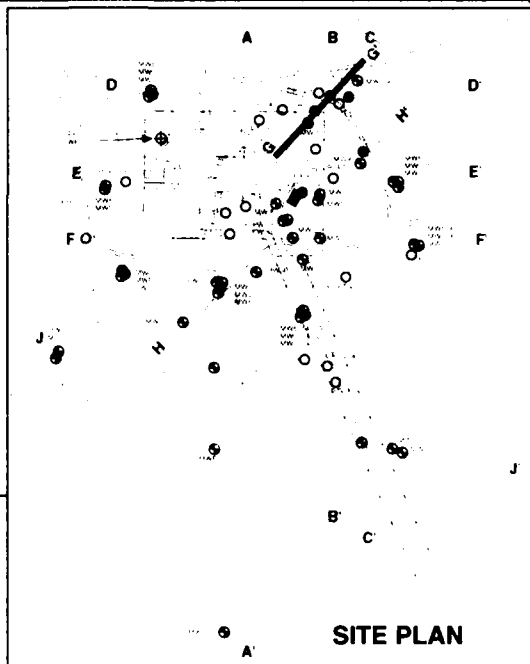
400

600

800

1000

3



SITE PLAN

Vadose
Zone

40

B
Zone

80

C
Zone

120

D
Zone

160

E
Zone

200

240

FIGURE 4-15
CROSS SECTION G-G'

DAVIS GLOBAL COMMUNICATIONS SITE
MCLELLAN AIR FORCE BASE
YOLO COUNTY, CALIFORNIA

CHM HILL

B-B'

F-F'

E-E' C-C'

DEPTH
(FT)

MWD-10
E127

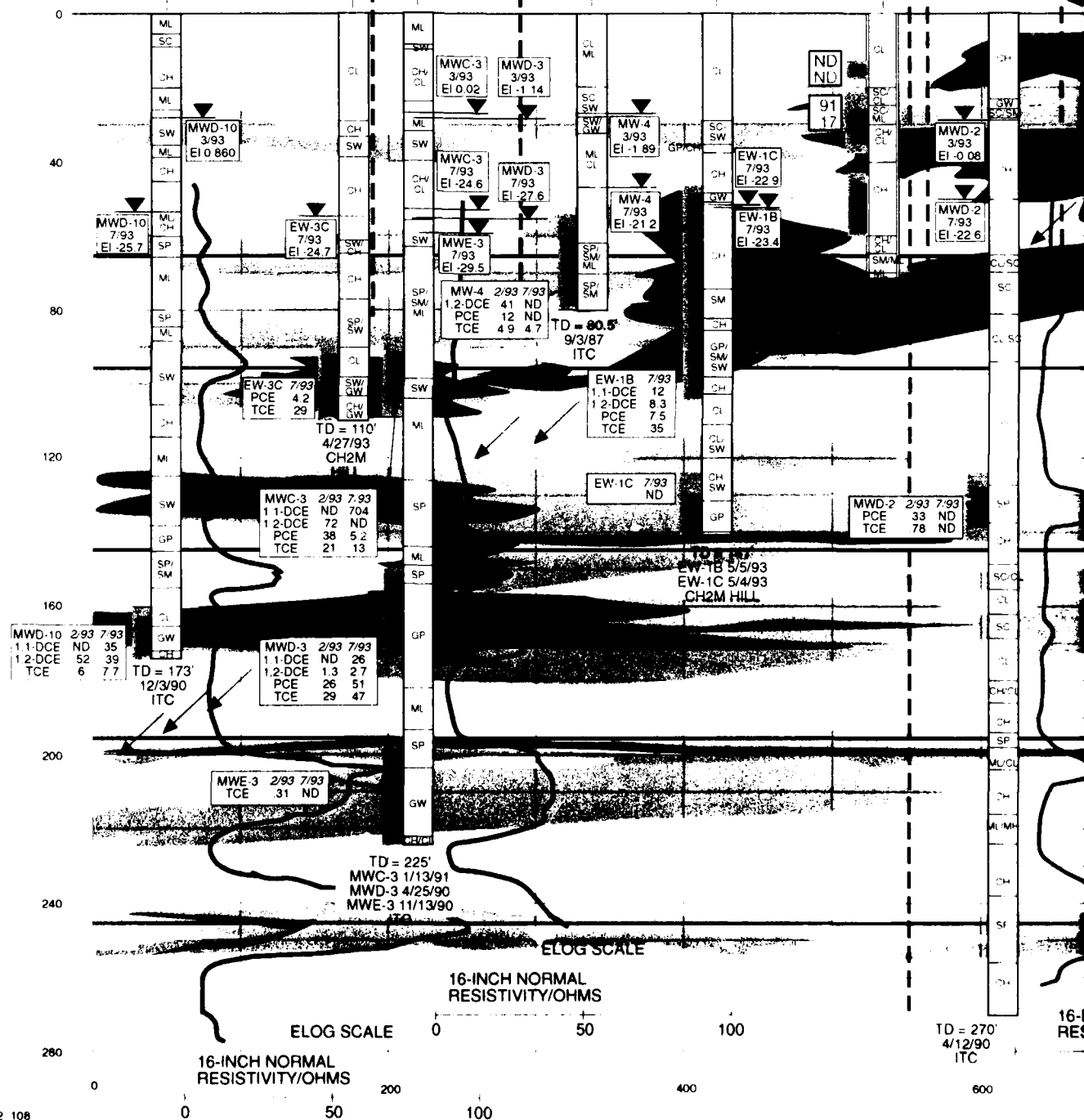
EW-30
EI 291

MWC-3
MWD-3
MWE-3
EI 27

MW-4
EI 25EW-1B
EW-1C
E| 29

P-5S
CH-5
P-5D
EI 28.5

MWD-2 (C)

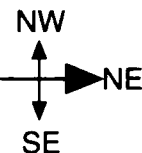
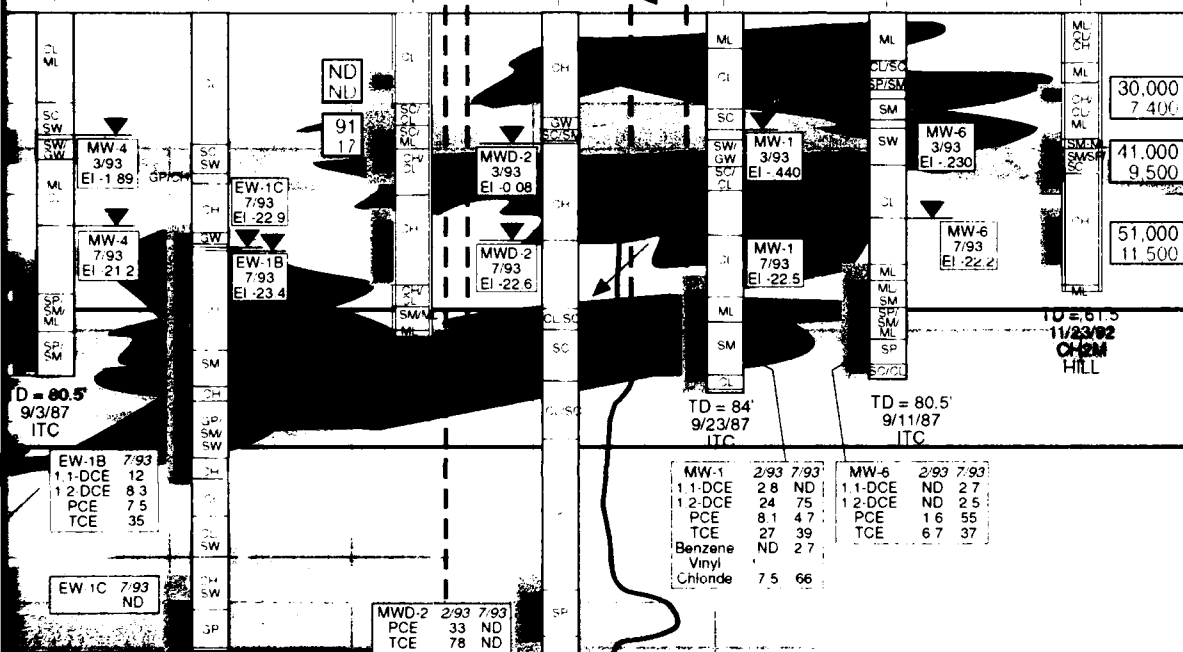


F-F'

B-B'

E-E' C-C'

H'

MW-4
EI 25EW-1B
EW-1C
EI 29P-5S
CH-5
P-5D
EI 28.5MWD-2 (C)
EI 28MW-1
EI 26MW-6
EI 23P-4S
CH-4
P-4D
EI 28COARSE-GRAINED
MATERIAL

FINE-GRAINED MATERIAL

LOG SCALE

MAL
OHMS

50 100

400

600

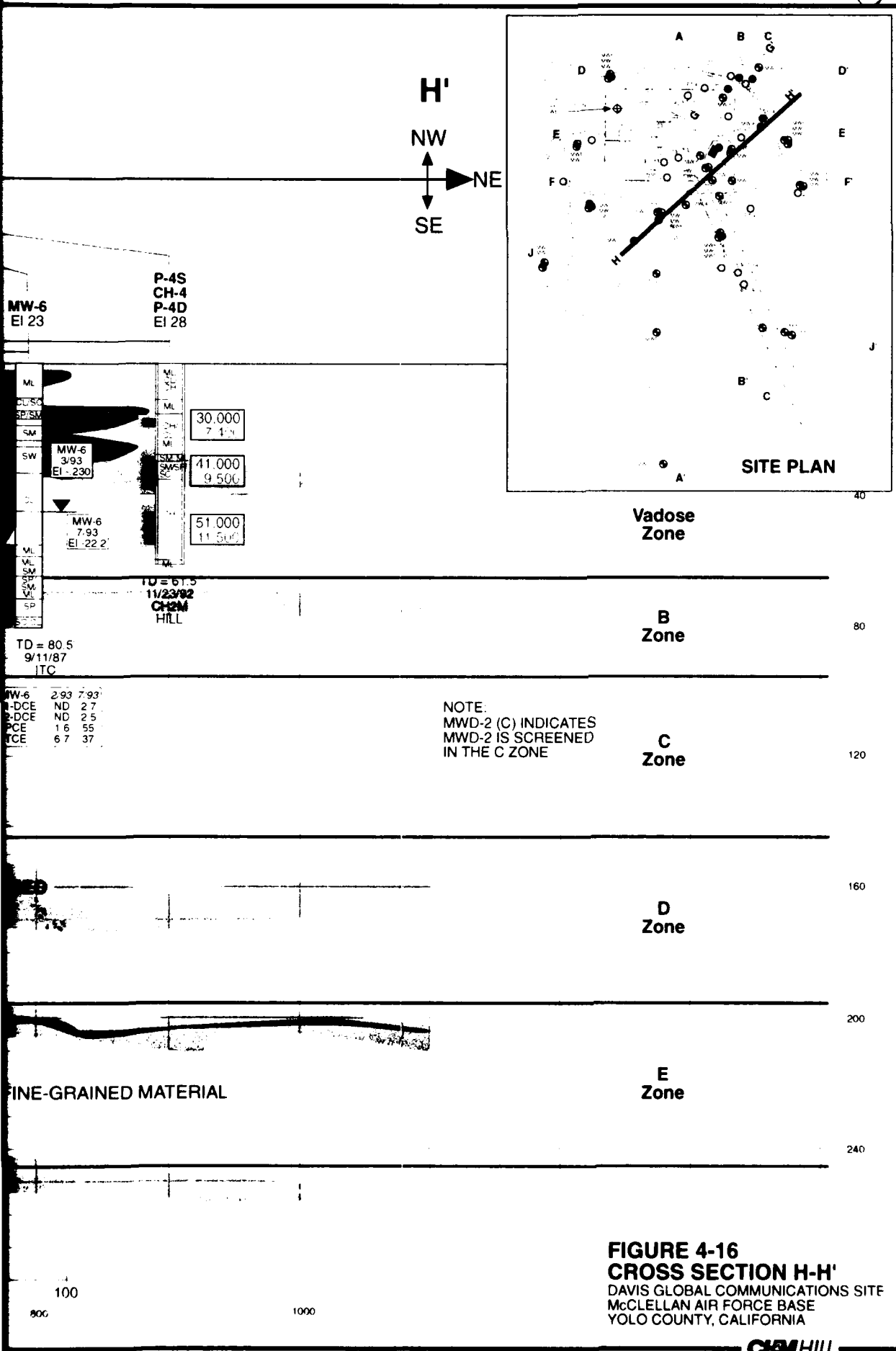
ELOG SCALE

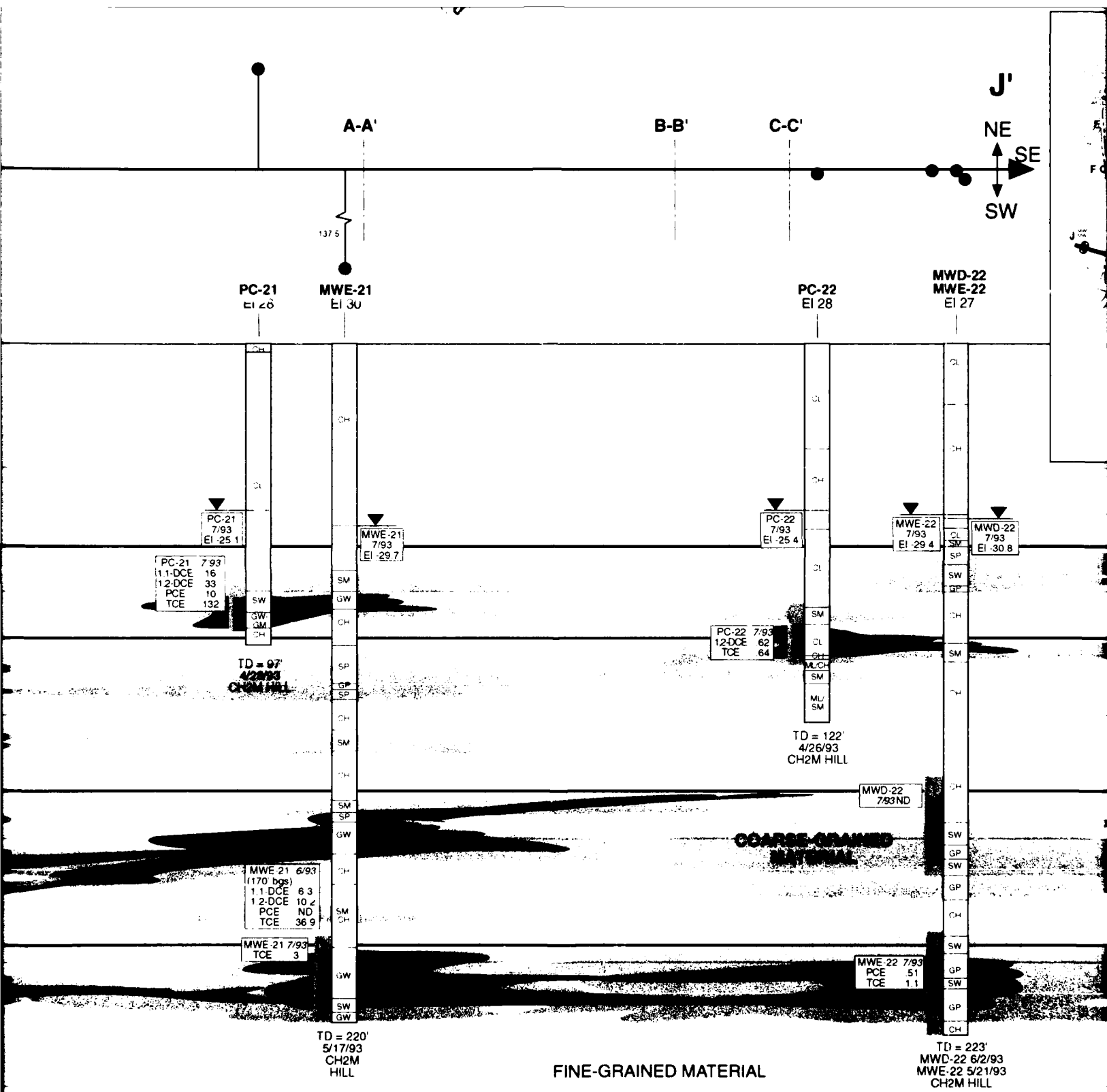
16-INCH NORMAL
RESISTIVITY/OHMS

50 100

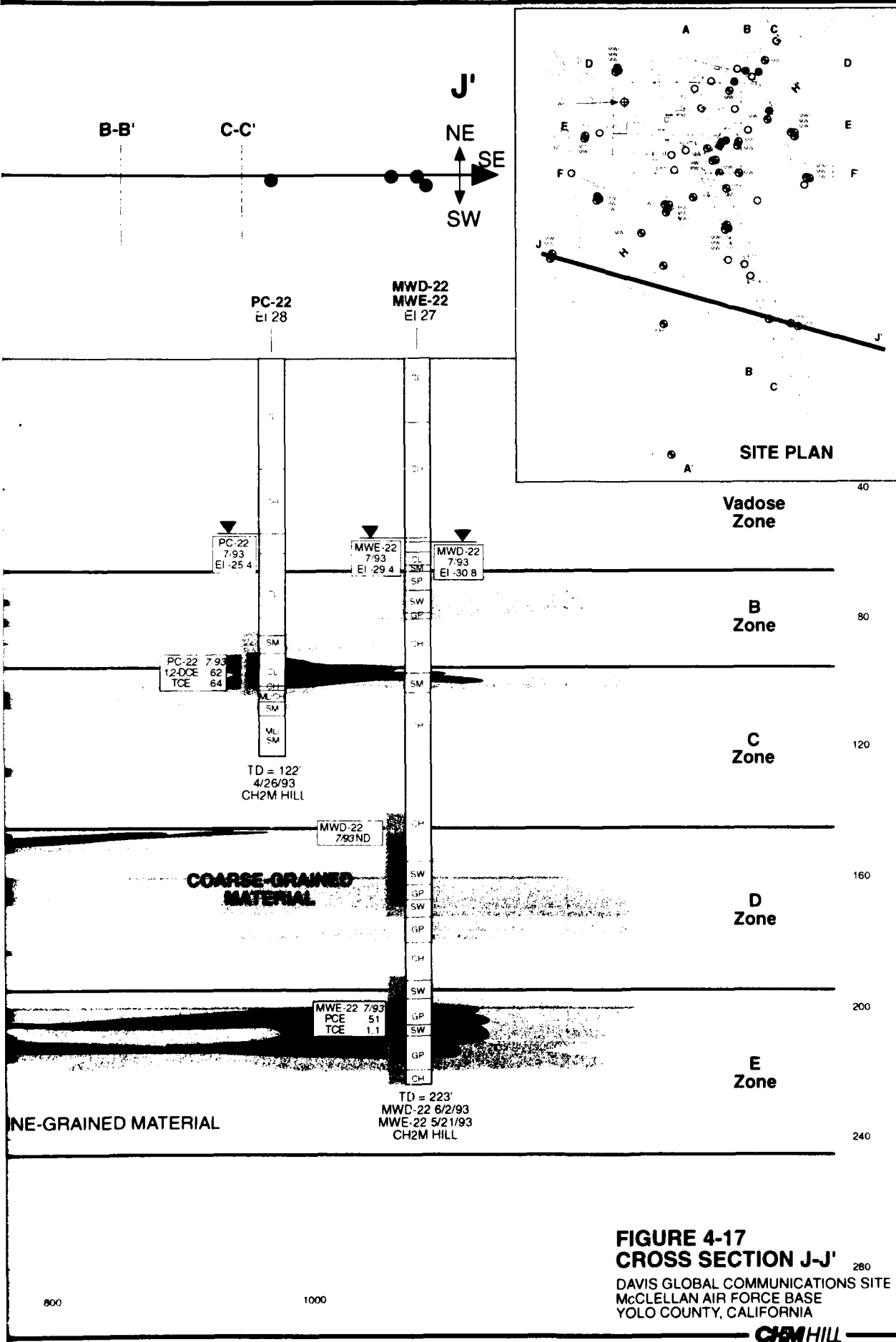
800

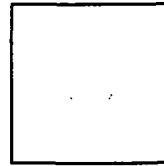
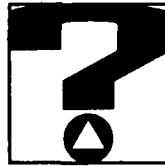
1000





3





Chapter 5 Problem Definition

This chapter presents a summary of the risk assessment, a description of ARAR compliance, and required cleanup levels for contaminants in each media. The risk assessment is based on health-based risk standards and regulatory guidelines for maximum contamination levels, as applied to the understanding of site hydrogeology and nature and extent of contamination described in Chapter 3 and 4, respectively.

5.1 Preliminary Risk Assessment

The preliminary risk assessment for the Davis Site used information developed through the remedial investigation (RI) to achieve the following:

- Identify potential chemicals of concern at the site.
- Identify potential exposure pathways from the chemicals of concern to human and ecological receptors.
- Estimate chemical concentrations that receptors could become exposed to through the identified potential exposure pathways.
- Estimate chemical intake rates through the identified potential exposure pathways.
- Characterize potential risks to humans and wildlife associated with estimated intake rates.

This preliminary risk assessment was based on a reasonable maximum exposure (RME) scenario and was developed in accordance with applicable federal, state, and Installation Restoration Program (IRP) guidance. In developing the RME scenario, the preliminary risk assessment used conservative assumptions that estimated exposures to site contaminants well above average exposure levels, but still within the range of possible exposures. The assumptions, methods, and data used in the preliminary risk assessment are presented in a Risk Assessment Report prepared concurrent with this report. This section summarizes the findings and conclusions from the preliminary risk assessment.

Contaminants of concern that were evaluated in the preliminary risk assessment were volatile organic compounds (VOCs) detected in soil gas and groundwater, and petroleum hydrocarbons and polynuclear aromatic hydrocarbons detected both in subsurface soil and in stockpiled soils. Generally, exposures to these contaminants were based on the highest

Exposure scenarios include inhalation of VOCs from soil water and ingestion or dermal contact with contaminants in excavated soils.

concentrations detected at the site. Exposure scenarios developed to evaluate risks to human health considered onsite workers potentially exposed by inhalation of VOCs emitted from soil gas or groundwater from the site production well, dermal contact with VOCs in groundwater, or soil ingestion and dermal contact with contaminants in excavated soils. Figure 5-1 shows a schematic diagram of the potential exposure scenarios.

Because of zoning restrictions in Yolo County, the site is not likely to be used for residential housing in the event of a change in mission of the facility. However, at the request of regulatory agencies, a hypothetical residential exposure scenario was evaluated, involving ingestion, inhalation, and dermal contact with VOCs detected in groundwater monitoring wells. Ecological resources potentially at risk are limited. However, there are two special status species that could use certain features of the site; these are Swainson's hawk and burrowing owl. Certain remediation activities could result in small losses in foraging habitat for Swainson's hawk. Burrowing owls using the stockpiled soils for nesting could potentially become exposed to petroleum hydrocarbons detected in the soil. With minimal dilution and ventilation in the burrows, hydrocarbon contaminants in the soil could reach equilibrium concentrations in air, resulting in potential inhalation exposures. In addition, two species of rare and endangered plants have been identified northeast and southwest of the fenced compound area: Colusa grass and Solano grass. However, these areas are not expected to be affected by remedial activities.

Ecological resources potentially at risk are limited to Swainson's hawk and burrowing owl.

Estimated health risks to humans are summarized in Table 5-1. The Environmental Protection Agency (EPA) generally considers action to be warranted at a site where cancer risks exceed 1×10^{-4} or a noncancer hazard index exceeds one. Risks falling in the 1×10^{-4} to 1×10^{-6} range may or may not require action, and are judged on a case-by-case basis. Risks less than 1×10^{-6} typically are not of concern to regulatory agencies. The results from the preliminary risk assessment indicate that some action may be required to reduce risks to human health associated with contaminants in groundwater. However, there are significant uncertainties in the risk estimates associated with contaminants in the site production well. Additional monitoring from the site production well may be warranted to better evaluate the presence and concentrations of ethylene dibromide (EDB) and trihalomethanes (such as chloroform) in water.

Diesel hydrocarbon concentrations in some samples from the stockpiled soils exceeded an ecological benchmark level for inhalation exposure, suggesting the presence of some risks to burrowing owls. Significant uncertainties are associated with the estimation of ecological exposures and with the benchmark level development. The ecological risk assessment tends to overestimate the risks associated with petroleum hydrocarbons in soil. However, the soil piles do not represent significant habitat and could be removed or graded with insignificant impacts to owl populations.

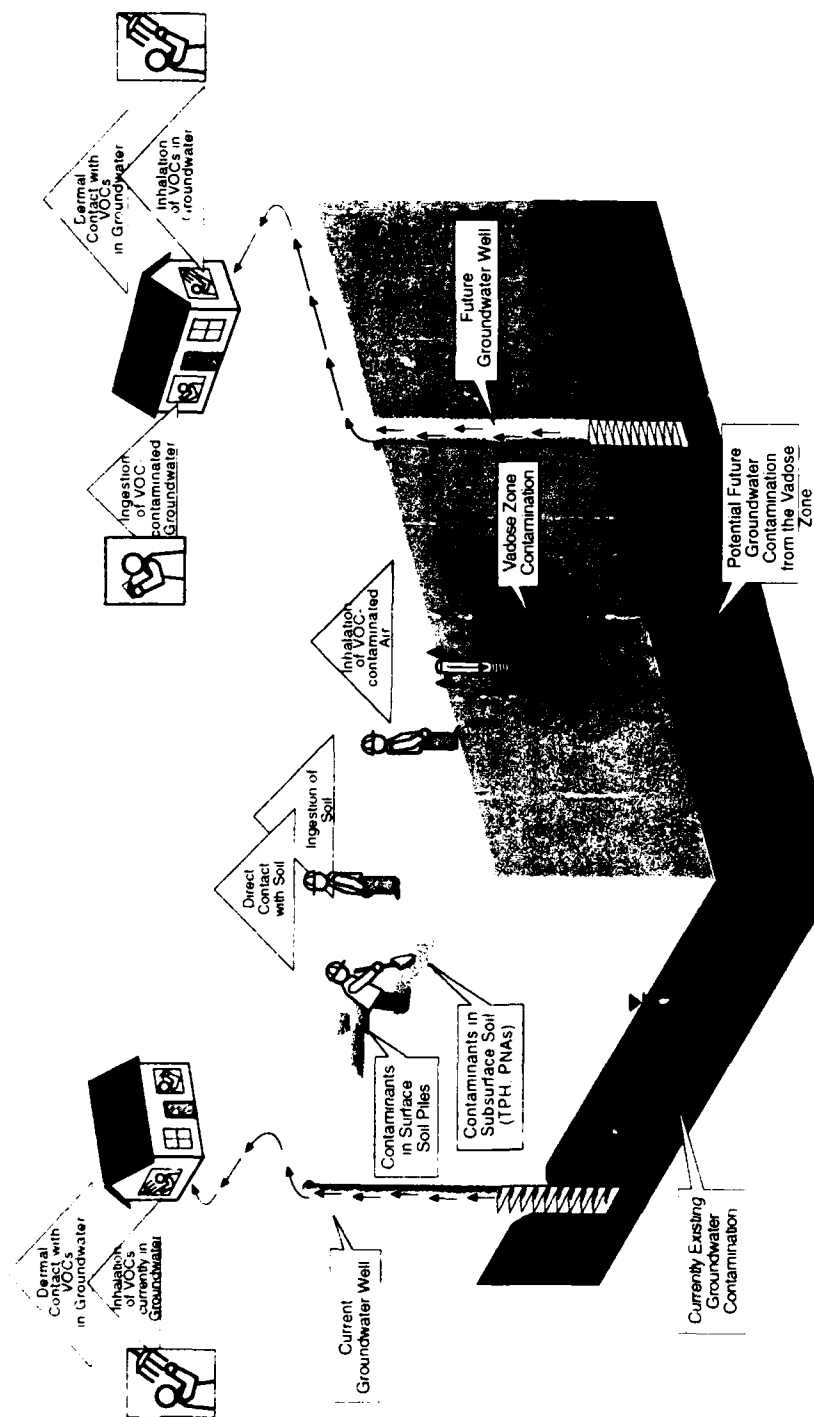


FIGURE 5-1
ILLUSTRATION OF
POTENTIAL EXPOSURE PATHWAYS
 DAVIS GLOBAL COMMUNICATIONS SITE
 MCCLELLAN AIR FORCE BASE
 YOLO COUNTY, CALIFORNIA

CHM HILL

Table 5-1 Summary of Estimated Human Health Risks ^a						
Receptor	Affected Media	Exposure Route	Cancer Risk Estimates		Noncancer Effects	
			Increased Lifetime Cancer Risk ^b	Chemicals Principally Contributing to Risks	Hazard Index ^c	Chemicals Principally Contributing to Noncancer Effects
Onsite worker-Outdoors	Soil gas, ground-water	Inhalation	3×10^{-7}	Tetrachloroethene in soil gas	<1	NA
Onsite worker-Excavation	Soil	Soil ingestion and dermal contact	5×10^{-9}	bis(2-ethylhexyl)phthalate in soil	<1	NA
Onsite worker-Indoors (Building 4708)	Soil gas, ground-water	Inhalation	4×10^{-5}	Tetrachloroethene in soil gas, EDB and chloroform in groundwater	<1	NA
Hypothetical future onsite resident ^d	Groundwater	Ingestion, inhalation, and dermal contact	7×10^{-4}	Tetrachloroethene and trichloroethene in groundwater	>1	Tetrachloroethene

^aHealth risk estimates based on RME scenarios.

^bNumerical risk estimates are not predictions of actual health outcomes. These estimates are calculated in a manner that overestimates risk, and therefore any actual risks are likely to be lower than these estimates and may even be zero. EPA generally considers action to be warranted at a site when cancer risks exceed 1×10^{-4} . Action may or may not be required for risks falling within 1×10^{-4} to 1×10^{-6} ; this is judged on a case-by-case basis. Risks less than 1×10^{-6} generally are not of concern to regulatory agencies.

^cHazard index greater than one indicates that there is some potential for adverse noncancer health effects associated with exposure to the contaminants of concern.

^dFuture residential use of the site is not likely, based on zoning requirements in Yolo County. Hypothetical scenario was included at regulatory agency request to evaluate aquifer nondegradation requirements.

5.2 Compliance with ARARs

The alternatives discussed in this Remedial Investigation/Feasibility Study (RI/FS) are required to attain cleanup standards and/or standards of control of hazardous substances which comply with applicable or relevant and appropriate requirements (ARARs). These requirements include federal environmental laws and more stringent state laws. Local regulations and guidelines must also be identified. Table 5-2 is a listing of the regulatory requirements included in the identification of potential ARARs.

ARARs are divided into three categories: chemical-specific, location-specific, and action-specific requirements. The chemical-specific ARARs for the Davis Site groundwater remedial actions define the concentration levels for contaminant in groundwater that trigger a problem and define concentration levels required for satisfactory treatment and end-use components for treated groundwater. Currently, no federal or state chemical-specific cleanup criteria exist for soil or soil gas. The location-specific ARARs relate to the geographical or physical location of the site, and the action-specific ARARs are requirements that define acceptable treatment and disposal procedures for hazardous substances. Appendix G, ARARs Analysis, discusses potential ARARs identified for the Davis Site, including two endangered grass species, Colusa and Solano.

The ARARs developed in this RI/FS are preliminary. Final ARARs will be developed and selected only after consideration of site-specific conditions; the results of risk assessment; negotiations with the agencies; and the evaluation of remedial actions such as extraction, treatment, and engineering controls to protect public health and the environment. ARARs identification will eventually be documented in the RAP.

5.3 Cleanup Goals for Each Medium

The cleanup goals selected for both the vadose zone and the groundwater includes restoring levels to background conditions. These cleanup goals were established by the Regional Water Quality Control Board (RWQCB) and Department of Toxic Substances Control (DTSC) during meetings with CH2M HILL and McClellan Air Force Base (McClellan AFB) in June 1993. For groundwater, this translates to a contaminant level of below detection, or <0.5 $\mu\text{g/l}$, for most constituents.

A cleanup goal is a target level that is both technically and economically attainable, but may not be achieved. Acceptable levels of cleanup are usually based on risk and may not be as stringent as the background condition cleanup goal. Risk-based cleanup goals may prove to be more feasible economically, but still capable of achieving defensible cleanup levels.

Table 5-2 Federal and State Requirements Included in the Identification of Potential ARARs	
Federal Requirements	
1.	Resource Conservation and Recovery Act (RCRA)
2.	Clean Water Act (CWA)
3.	Safe Drinking Water Act (SDWA)
4.	Clean Air Act (CAA)
5.	Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)
6.	Superfund Amendments and Reauthorization Act (SARA)
7.	National Archaeological and Historic Preservation Act
8.	National Historic Preservation Act
9.	Endangered Species Act
10.	Wilderness Act
11.	Fish and Wildlife Coordination Act
12.	Scenic Rivers Act
13.	Coastal Zone Management Act
14.	Marine Protection Resources and Sanctuary Act
15.	Executive Order on the Protection of Wetlands
16.	Executive Order on the Protection of Flood Plains
17.	Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)
18.	Toxic Substances Control Act (TSCA)
19.	Occupational Safety and Health Act (OSHA)
20.	Standards for Transportation of Hazardous Wastes
State Requirements	
1.	California Regional Water Quality Control Board Standards (RWQCB)
2.	California Code of Regulations (CCR)
3.	State Water Resources Control Board (SWRCB)
4.	California Air Resources Board (CARB)
5.	Hazardous Waste Control Law
6.	State Superfund
7.	California Endangered Species Act
8.	California Fish and Game Code Sections
9.	Department of Health Services Office of Drinking Water (DHS)
10.	Yolo-Solano Air Pollution Control District Rules and Guidelines
11.	Yolo County Department of Environmental Health Guidelines
12.	Porter-Cologne Water Quality Control Act



Chapter 6 Feasibility Study

This chapter evaluates different remedial alternatives that could be used to clean up the vadose zone and groundwater contamination. The remedial alternatives are evaluated based on current understanding of the site hydrogeology and nature and extent of contamination presented in Chapters 3 and 4.

The following three remedial response objectives have been developed by the California Regional Water Quality Control Board (RWQCB), the Department of Toxic Substances Control (DTSC), and McClellan Air Force Base (McClellan AFB) for the Davis Global Communications Site (Davis Site):

- Reduce or eliminate levels of subsurface contamination that pose a potential threat to human health or the environment.
- Prevent the spread of groundwater contamination beneath the site, especially to regional aquifers.
- Provide implementable strategies for remedial actions as quickly as possible and still maintain compliance with the Federal Facilities Site Remediation Agreement (FFSRA) schedule.

The remedial action that is eventually selected from the range of alternatives presented in this chapter should be checked against these remedial response objectives to make sure that the action is in fact adequate.

6.1 Approach to the Feasibility Study

This Feasibility Study focuses on remedial action alternatives for two different media of concern: the vadose zone (soil above the water table) and the groundwater. Potential remedies for the vadose zone are developed based on their ability to remove volatile organic compounds (VOCs) only.

There is also an area of the vadose zone that is contaminated with heavier petroleum hydrocarbons that do not exhibit any appreciable volatility, as described in Chapters 1 and 4. This zone of contamination is the subject of a bioventing treatability study being conducted by Engineering-Science, Inc., and is not addressed in this chapter. More detail on the nature of the petroleum hydrocarbon contamination and potential options that could be used to mitigate the problem are discussed in Appendix K, Hydrocarbon Remediation Options.

No-action cleanup options are presented for both the vadose zone and groundwater to provide a baseline against which the actions can be compared. In any feasibility study, the National Oil and Hazardous Substances Contingency Plan (NCP) requires that no action be carried through the detailed analysis of alternatives.

With the exception of no-action, the vadose zone and groundwater clean-up options evaluated herein may be thought of as consisting of three different components: (1) *Capture* of the contamination in the subsurface, (2) *Treatment* of the resulting contaminated airstream or water stream that is extracted from the subsurface, and (3) *End-use* of the airstream or water stream after treatment. The descriptions presented in this chapter follow this logic by describing first the capture, then the treatment, and finally the end-use components for each cleanup option.

Cleanup options evaluated for VOCs in the vadose zone are no-action and soil vapor extraction (SVE). Other possible actions for remediating VOCs in the vadose zone such as capping or excavation are not evaluated in this RI/FS because they are thought to be either too costly or ineffective when compared to SVE.

Cleanup options evaluated for groundwater contamination are no-action and groundwater extraction. Other options to remediate the groundwater such as in situ treatment are not evaluated in this RI/FS because their ability to address the groundwater contamination given the hydrogeologic conditions at the Davis Site has not been proven.

The cleanup options for the vadose zone and groundwater may be assembled into four different sitewide *alternatives* as illustrated in Table 6-1. In Section 6.3 of this chapter, the alternatives are evaluated and compared to assist the decisionmakers in selecting the proper action for the Davis Site.

Each Cleanup Option Consists of Three Components:

- *Capture*
- *Treatment*
- *End Use*

Two Different Cleanup Options are Evaluated for the Vadose Zone and Groundwater:

- *Vadose Zone:*
 - *No-Action*
 - *Soil Vapor Extraction*
- *Groundwater:*
 - *No-Action*
 - *Groundwater Extraction*

Table 6-1 Summary of Alternatives				
Alternative	Cleanup Options			
	No-Action Vadose Zone	No-Action Groundwater	Soil Vapor Extraction	Groundwater Extraction
Alternative 1	✓	✓		
Alternative 2		✓	✓	
Alternative 3	✓			✓
Alternative 4			✓	✓

6.2 Description of Cleanup Options

This section provides a description of the four cleanup options:

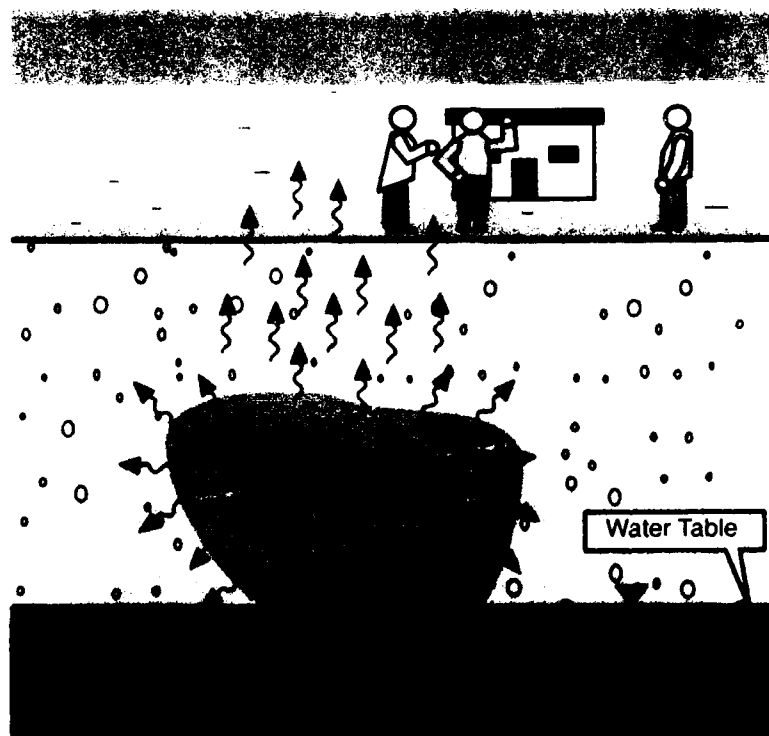
- No-action for the vadose zone
- No-action for the groundwater
- Soil vapor extraction
- Groundwater extraction

The capture, treatment, and end-use components for the SVE and groundwater extraction cleanup options are also described in this section.

6.2.1 No-Action-Vadose Zone

For the vadose zone, the no-action cleanup option would leave the VOC contaminants in place where they would be allowed to continue to migrate and transform in the subsurface. Specifically, the contaminants might become entrained in infiltrating rainwater and percolate downward to groundwater via liquid advection (see Figure 6-1).

For the vadose zone, no action would leave VOC contaminants in place, where they will continue to migrate and transform in the subsurface.



**FIGURE 6-1
SUBSURFACE CONDITIONS
UNDER THE NO-ACTION
ALTERNATIVE**

Preliminary contaminant transport modeling has been performed using the VLEACH computer program to estimate the incremental impacts that contaminants in the vadose zone today would have on the groundwater in the future, if no action is taken. This analysis only considered contamination in the upper 40 feet of the subsurface. The soils between 40 and 70 feet depth are saturated for most of the year; therefore, contamination

in this zone was not included in the analysis. The transport analysis focused on tetrachloroethene (PCE) only, on the basis that PCE represents greater than 90 percent of the total VOC mass in the vadose zone (refer to Chapter 4). Appendix H, Analysis of Vadose Zone Contamination Impacts, provides a description of the modeling assumptions, limitations, and results. Modeling results indicate contaminants in the upper 40 feet of the vadose zone represent an additional long-term source of groundwater contamination, creating peak incremental groundwater concentrations that may range from 20 to 80 µg/l, well in excess of regulatory standards. These predicted incremental concentrations are due solely to contaminant mass moving from the vadose zone into the groundwater and do not take into account the contaminant mass that is already in the groundwater.

6.2.2 No-Action-Groundwater

For groundwater, the no-action cleanup option would allow contaminants in the saturated zone to remain in place where they would move laterally and vertically and would eventually exit the site boundaries, as shown in Figure 6-1. The contaminants would generally move in the direction of groundwater flow. As described in Chapter 3, groundwater flow directions vary greatly both spatially and temporally under the Davis Site, and the contaminants in the groundwater would be expected to do the same. Lateral groundwater flow directions are shown in Figure 3-4; vertical flow directions are illustrated in Figure 3-5.

For the groundwater, no action would leave VOC contaminants in the saturated zone where they will move laterally and vertically until leaving the site boundaries.

6.2.3 Soil Vapor Extraction

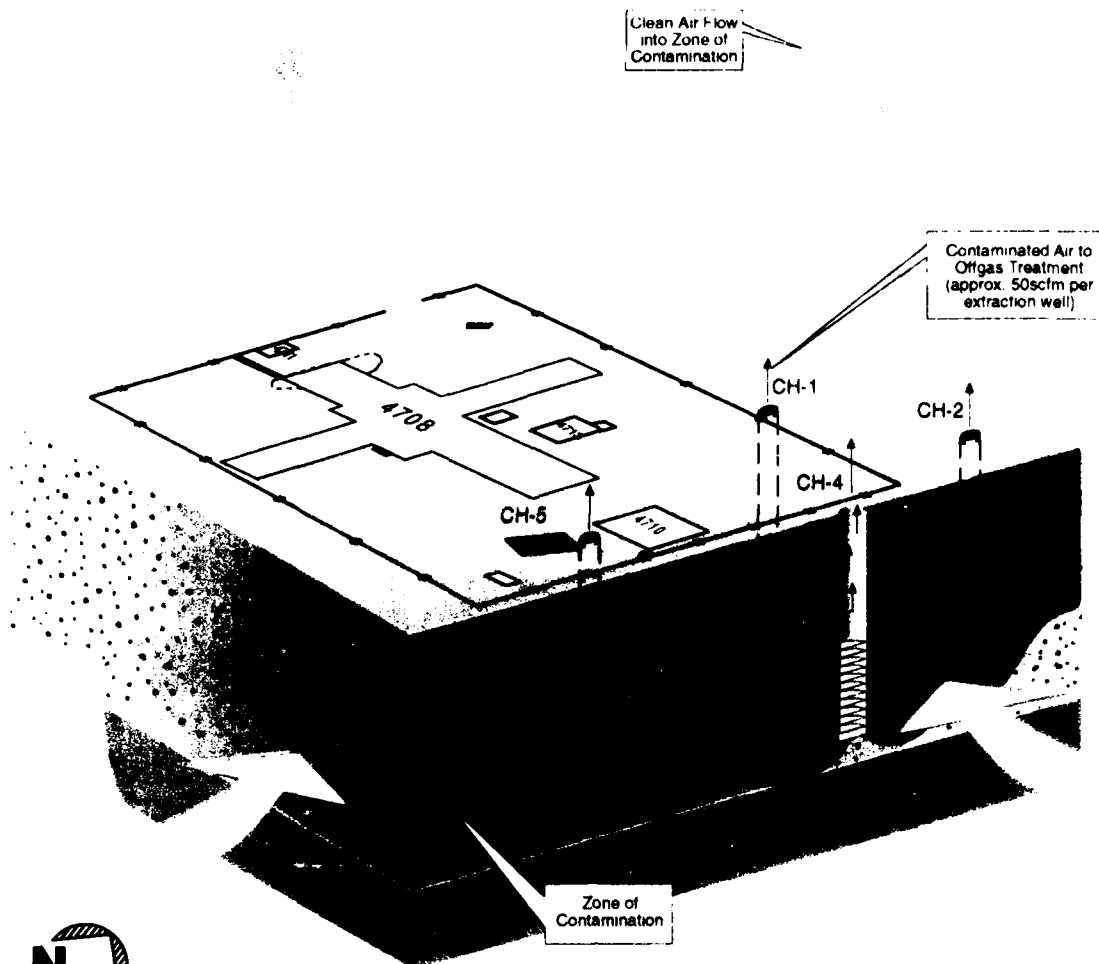
6.2.3.1 Capture Components

SVE will be used as a mechanism for collecting vadose zone contamination. An SVE system captures the VOCs in the vadose zone by applying a vacuum to the subsurface and inducing airflow through soils containing VOCs and collecting the contaminated soil gas through extraction wells.

At the Davis Site, the estimated extent of VOC contamination is as shown on Figure 4-2a of Chapter 4. The target zone boundary shown on Figure 4-2a is based on soil gas data obtained down to depths of approximately 40 feet below ground surface (bgs). The SVE system discussed here only addresses contamination in the upper 40 feet of the subsurface. The dual-phase extraction innovation discussed in Section 6.4.2 provides one technique that could be used to address the 40- to 70-foot zone, which is saturated for most of the year (see Appendix O, Evaluation of Dual-Phase Extraction).

Capture of the vadose zone contamination can occur by applying a vacuum through existing Monitoring Wells CH-1, CH-2, CH-4, and CH-5.

SVE modeling of the site indicates that capture of the vadose zone contamination can be achieved by applying a vacuum through existing Soil Vapor Monitoring Wells (SVMWs) CH-1, CH-2, CH-4, and CH-5, and in effect turning these wells into extraction wells. Air flow rates of approximately 50 scfm are required at each well to provide capture. Appendix I, Analysis of Soil Vapor Extraction, provides more details on the airflow modeling assumptions and results for the Davis Site. Figure 6-2 illustrates the extraction well layout.



**FIGURE 6-2
CAPTURE OF VADOSE ZONE
CONTAMINATION THROUGH SVE**

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As shown in Figure 6-2, operation of the SVE system will develop a flow of clean air into the contaminated soil where the air will pick up contamination and exit through the extraction wells. The continued replacement of contaminated pore air with uncontaminated air leads to the gradual decontamination of the soil. The time required to capture and remove the contamination from the vadose zone is estimated by assuming a required number of *pore volume exchanges*. A pore volume is the volume of all the air in the soil pore spaces within the region of contamination. One pore volume exchange represents the movement of one pore volume of air through the soil as a result of the SVE system flow. Historically, the number of pore volume exchanges needed to achieve remediation of a site varies greatly, ranging anywhere from several hundred to several thousand (personal communication, Jim Hartley, 1993). For the Davis Site, 1,000 pore volume exchanges were assumed necessary to achieve cleanup. This corresponds to an estimated operating time frame of approximately 10 years for the SVE system, based on modeling presented in Appendix I.

Subsurface monitoring is an important aspect of any operating SVE system. SVMWs CH-1, CH-2, CH-4, and CH-5 can serve a dual purpose as extraction wells and also as subsurface monitoring points when their applied vacuums are temporarily turned off. In addition, SVMW CH-3 and Piezometers P1-S, P-1D, P-2M, P-3S, P-3D, P-4S, P-4D, P-5S, and P-5D will provide other monitoring locations. Construction details for all of these wells and piezometers, including screened intervals, are provided in Table 2-2. Additional monitoring points may need to be installed for the zone of seasonal water table fluctuation, located 40 to 70 feet bgs. Costs for installing additional wells are not included in the estimates presented in Section 6.3.7. A description of air permeability testing at CH-1, CH-4, and CH-5 is included in Appendix B, Air Permeability Testing.

Subsurface monitoring of the SVE system will provide data regarding the extent of propagation of subsurface vacuums caused by the network of extraction wells. This information would be used to check if the zone of subsurface airflow is occurring through the entire zone of subsurface contamination. Soil gas samples can also be periodically obtained from the monitoring points to estimate the rate of decontamination. At a minimum, monitoring should be conducted quarterly to assess the subsurface airflows and rates of decontamination.

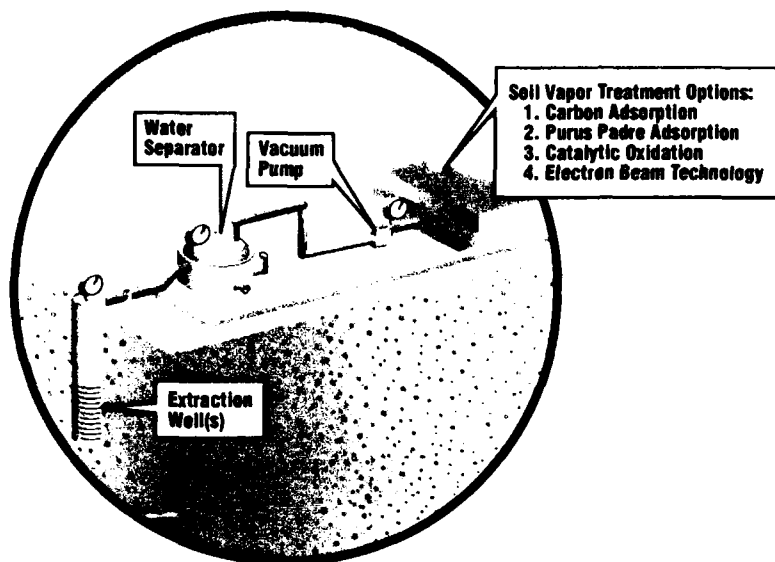
6.2.3.2 Treatment Components

In an SVE system contaminated air, or *offgas*, is removed from the subsurface. Before being discharged into the atmosphere, this contaminated airstream will require some form of treatment to remove the contamination. Initially, four different offgas treatment components were evaluated as possible options at the Davis Site: Electron Beam Technology (EBT), Catalytic Oxidation (CatOx), Gas Phase Carbon Adsorption (GAC), and Synthetic Resin Adsorption Systems (Purus PADRE), as shown in Figure 6-3. Detailed descriptions and evaluations of these options are presented in Appendix L, Vadose Zone Treatment Options.

The adsorptive offgas treatment options (GAC and Purus PADRE) are not the best methods to use at the Davis Site because they do not effectively remove methane or vinyl chloride, both of which have been detected at the Davis Site. EBT is a possible offgas treatment component that could work at the Davis Site, but is not yet proven at removing VOCs from contaminated airstreams. More discussion on EBT and its possible application at the Davis Site is provided in Section 6.4.1.

CatOx units have demonstrated success at removing over 99 percent of contaminants from waste streams similar to those found at the Davis Site, including vinyl chloride and methane. In addition, as described in Appendix L, CatOx is cost competitive with the other offgas treatment technologies. For these reasons, the detailed evaluation of SVE presented in Section 6.3 will generally assume a CatOx offgas treatment component.

Catalytic oxidation units have demonstrated success at removing over 99 percent of contaminants from offgas waste streams similar to those found at the Davis Site.

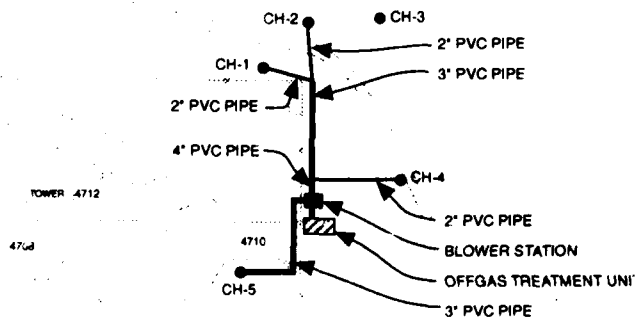


**FIGURE 6-3
SVE VAPOR TREATMENT
SCHEMATIC**

A centralized offgas treatment facility is assumed for the Davis Site. Manifold piping will be used to collect the offgas from the individual extraction wells and route it to a CatOx unit located to the east of Building 4710.

6.2.3.3 End-Use Components

The simplest end-use component for air is to discharge it directly into the atmosphere after it has been treated. Before being discharged, the airstream would be sampled and tested to make sure that it complies with air quality requirements. Figure 6-4 is a schematic of the manifold piping, blower station, and offgas treatment unit for the SVE system.



LEGEND

● SOIL VAPOR MONITORING WELL



SCALE (Approximate)

0 200 FEET

**FIGURE 6-4
SVE SYSTEM LAYOUT**
 DAVIS GLOBAL COMMUNICATIONS SITE
 MCCLELLAN AIR FORCE BASE
 YOLO COUNTY, CALIFORNIA

6.2.4 Groundwater Extraction

6.2.4.1 Capture Components

A groundwater extraction system is the option that will be used to capture and remove contamination in the groundwater. A groundwater extraction system captures contaminated groundwater by pumping the groundwater via a network of wells equipped with submersible pumps. The wells are designed to capture all water within a previously specified "target volume." Contaminated water is pumped from the target volume via groundwater extraction wells.

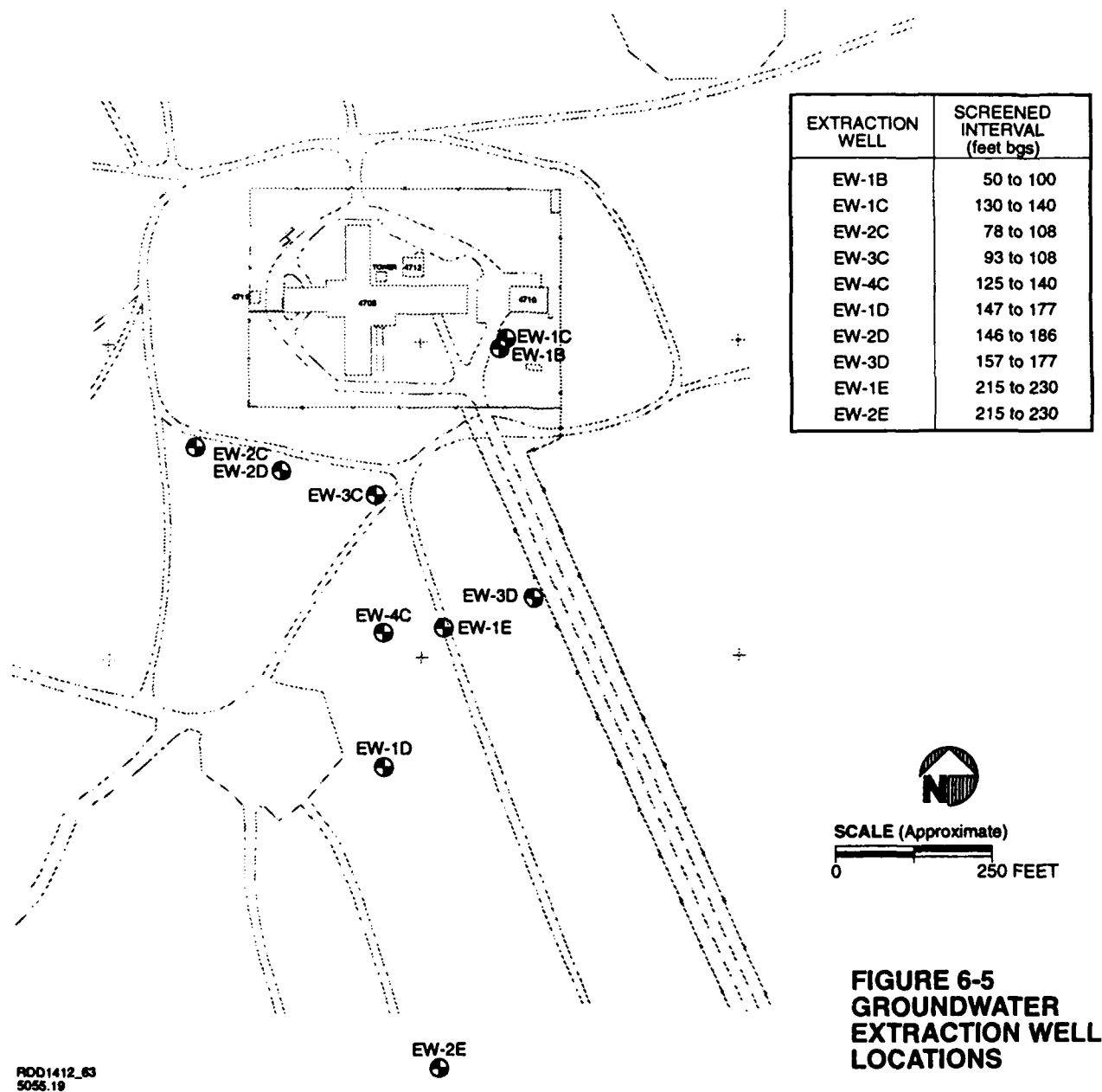
As described in Chapters 3 and 4, four water-bearing alluvial units that are contaminated have been identified beneath the Davis Site. Starting with the shallowest unit these have been named the B, C, D, and E aquifers, respectively. The aquitards have in turn been named the A-B, B-C, C-D, and D-E aquitards. The majority of the groundwater contamination (83 percent) has been found in the upper B and C aquifers and corresponding A-B and B-C aquitards (refer to Table 6-2). To provide decisionmakers with an estimate of the incremental effort necessary to go from removing 83 percent of the entire mass (i.e., mass from the B and C aquifers and A-B and B-C aquitards) versus removing all of the mass, two different target volumes are evaluated:

- Target Volume 1 = B and C aquifers and A-B and B-C aquitards only
- Target Volume 2 = All four aquifers and aquitards.

Table 6-2
Contaminant Mass and Extraction Rate for Each Hydrogeologic Unit

Unit	Extraction Rate (gpm)	Estimated Total Mass (kg/lb)	Cumulative Mass (%)
A-B Aquitard		63.50/139.70	22.7
B Aquifer	80	81.73/179.81	29.2
B-C Aquitard		52.2/115	18.7
C Aquifer	300	33.8/74	12.1
Subtotal	380	231.23/509	82.7
C-D Aquitard		25.4/56	9.1
D Aquifer	260	16.0/35	5.7
D-E Aquitard		7.1/16	2.5
E Aquifer	180	0.13/0.29	0.05
Total	820	279.86/617	100.00

Figures 4-1b and 4-1c show the extent of the target volumes in plan view. The proposed extraction well layout is illustrated in Figure 6-5. The aquifer targeted by each well is identified by the last letter in the well name (e.g., EW-1B targets the B aquifer).



The A-B aquitard is saturated only during the winter months, and partially or fully desaturates during the summer because of a groundwater depression that can be attributed to regional pumping. Contaminants in the A-B aquitard will be captured by the groundwater extraction system only when the zone is saturated. An innovative option exists to treat this zone of seasonal water table fluctuation, called *dual-phase extraction*. This innovation would remove contaminants from both the water and air phases from a single well. Section 6.4.2 and Appendix O provides more detail on this process.

Four extraction wells are needed to capture contamination from the B and C aquifers and A-B and B-C aquitards, pumping at 380 gpm.

According to groundwater capture curve modeling discussed in Appendix J, Groundwater Modeling (MicroFem), four extraction wells are needed to capture the contamination in the B and C aquifers and A-B and B-C aquitards, with an estimated required flow rate up to 380 gpm; nine extraction wells are needed to capture contaminated groundwater from all of the units with an estimated flow rate up to 820 gpm. These extraction rates were considered adequate to capture the target volumes under summer groundwater conditions. During winter conditions, total flow rates can be reduced to one-third of the summer condition extraction rates.

Nine extraction wells are needed to capture contamination from all aquifers and aquitards, pumping at 820 gpm.

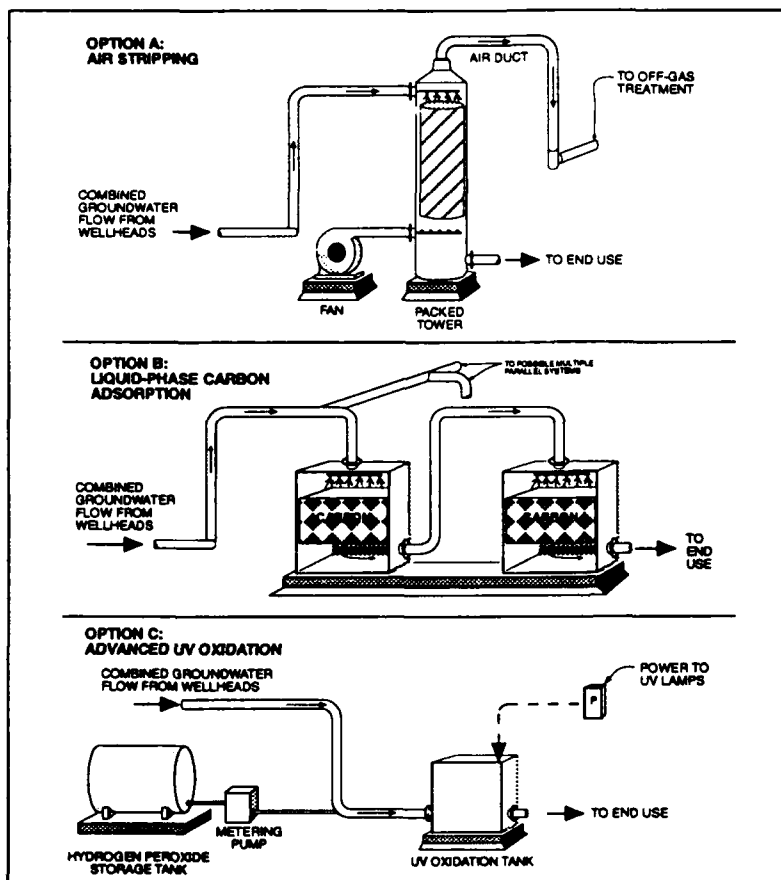
Monitoring is a necessary component of the groundwater extraction system. Water level measurements need to be taken from monitoring wells to assess if the groundwater within the target volume is being hydraulically captured. Water quality data need to be taken to monitor possible changes in the target volume geometry and also to characterize the influent water stream that enters the groundwater treatment system. Recommended monitoring locations and monitoring frequency during operation of the groundwater extraction system is discussed in Appendix J.

The time of operation of the groundwater extraction system is difficult to estimate and depends on the number of pore volumes needed to flush out the contamination. At the Davis Site, 10 pore volumes or more may be required to clean up the groundwater. This could correspond to groundwater extraction operation of 30 years or longer at the Davis Site. Groundwater extraction times could be on the order of centuries based on vadose zone modeling, if the contamination that currently resides in the vadose zone is allowed to continue to migrate into the groundwater.

6.2.4.2 Treatment Components

Contaminated water that is extracted from the subsurface requires treatment before it can be reused in some manner. Three different methods are presented as possible options to treat the groundwater: advanced UV oxidation, sorption onto activated carbon (GAC), and air stripping as illustrated in Figure 6-6.

In the case of air stripping, the contaminants are removed from the water and entrained into an airstream. The resulting contaminated airstream would be conveyed to the SVE offgas treatment component for treatment. Detailed descriptions and evaluations of the different water treatment components are provided in Appendix M(a), Groundwater Treatment Options.



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**FIGURE 6-6
WATER TREATMENT OPTIONS**

The advanced UV oxidation system uses ultraviolet (UV) light in combination with an oxidant, such as hydrogen peroxide, to oxidize the contaminants in the groundwater. As described in Appendix M(a), basic advanced UV oxidation is a proven option that will work for the groundwater contaminants at the Davis Site. There are also a variety of innovative enhancements to the standard advanced UV oxidation system, which are designed to improve the efficiency of the system. More discussion regarding innovative advanced UV oxidation techniques can be found in Section 6.4.1.

GAC and air stripping are both options that will work for the contaminated water stream at the Davis Site. However, for the purposes of the detailed evaluation, conventional advanced UV oxidation is selected as the representative treatment technology. Selection of a different treatment system during remedial design should not significantly alter the conclusions of the detailed evaluation.

Advanced UV oxidation is a proven option that will work for the groundwater contaminants at the Davis Site.

Advanced UV oxidation system enhancements are in various stages of development, and progress on them should be monitored periodically.

As with the SVE option, the extracted groundwater will be collected in manifold piping from the well heads and routed to a centralized advanced UV oxidation treatment facility located to the southeast of Building 4710.

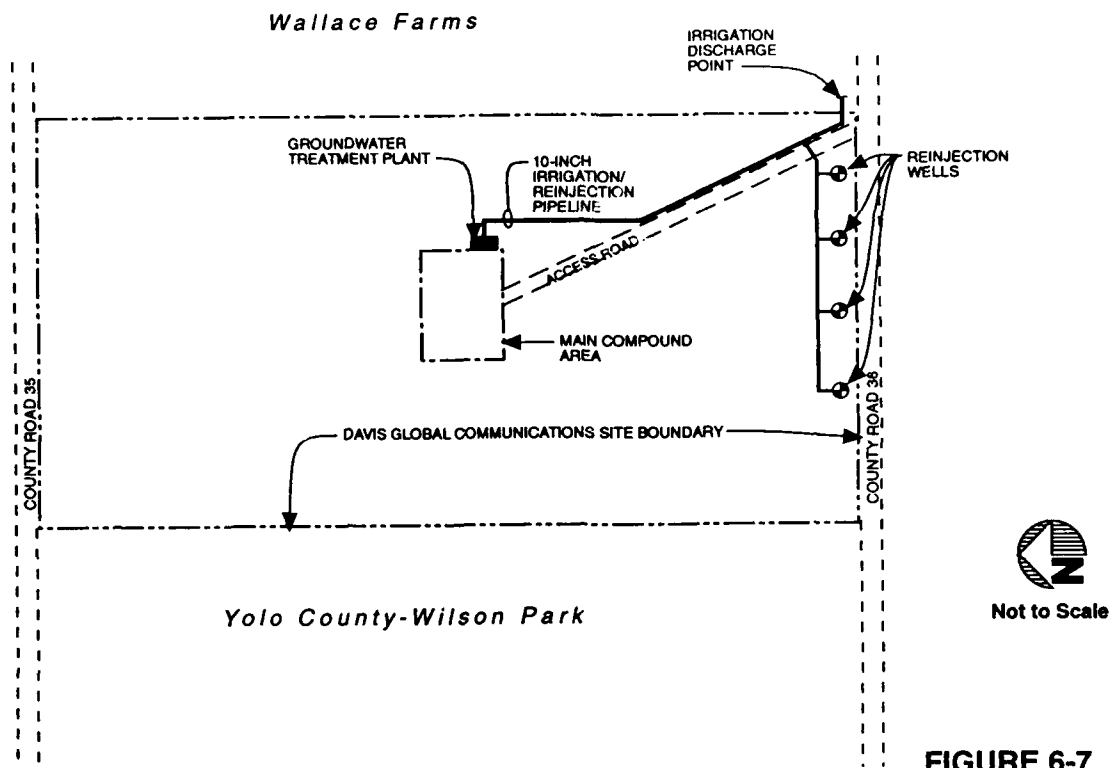
6.2.4.3 End-Use Components

A groundwater end-use component has been developed to provide a beneficial use for the treated groundwater from the Davis Site. Initially, five end-use components were developed and evaluated as possible options: Wilson Park irrigation, Wallace Farms irrigation, surface-water discharge to Putah Creek, onsite groundwater reinjection, and onsite irrigation. Detailed descriptions and evaluations of these components are presented in Appendix M(b), Groundwater End-Use Components. The end-use component evaluation presented in Appendix M(b) builds upon the original end-use analysis presented in the Intermediate Design Report for the Design Report for the Davis Site (CH2M HILL, 1993b).

Using screening criteria including cost, management, timely construction, and system reliability, two end-use components seem to best suit the Davis Site: Wallace Farms irrigation and onsite groundwater reinjection. The flow of treated groundwater may vary between 380 gpm and 820 gpm depending on the selected target volume (refer to Appendix J) and time of year. It is anticipated that Wallace Farms would beneficially use all of the treated water between April 1 and October 31. Onsite groundwater reinjection will serve as the end-use system between November 1 and March 31 and will also function as the summertime backup.

As a first step to drilling reinjection wells, exploratory test holes should be drilled to define the stratigraphy and presence of coarse-grained units. An attempt should be made to collect aquifer soil samples. The samples should be analyzed to determine if the soil matrix is compatible with the injection water in terms of geochemistry and aquifer clogging. Geophysical logging of the test hole and logging of the test hole cuttings will give an indication of the hydraulic properties of the formation.

The Wallace Farms irrigation and the onsite groundwater reinjection components would consist of a common pump station at a centralized Davis Site treatment plant, a pipeline to convey water to the headworks of the irrigation system, a pipeline to the reinjection wells, three reinjection wells, one backup reinjection well, telemetry, and automatic valving and controls. The groundwater end-use component is outlined in Figure 6-7.



**FIGURE 6-7
GROUNDWATER END
USE COMPONENTS**

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6.3 Detailed Evaluation of Alternatives

Descriptions of the different options that could be used to remove contamination from the vadose zone and groundwater at the Davis Site were presented in Section 6.2. These options have been assembled into four different sitewide alternatives as shown in Figure 6-8. SVE and groundwater extraction each consist of three different components: capture, treatment, and end-use. The specific components assumed for the SVE and groundwater extraction systems are as listed:

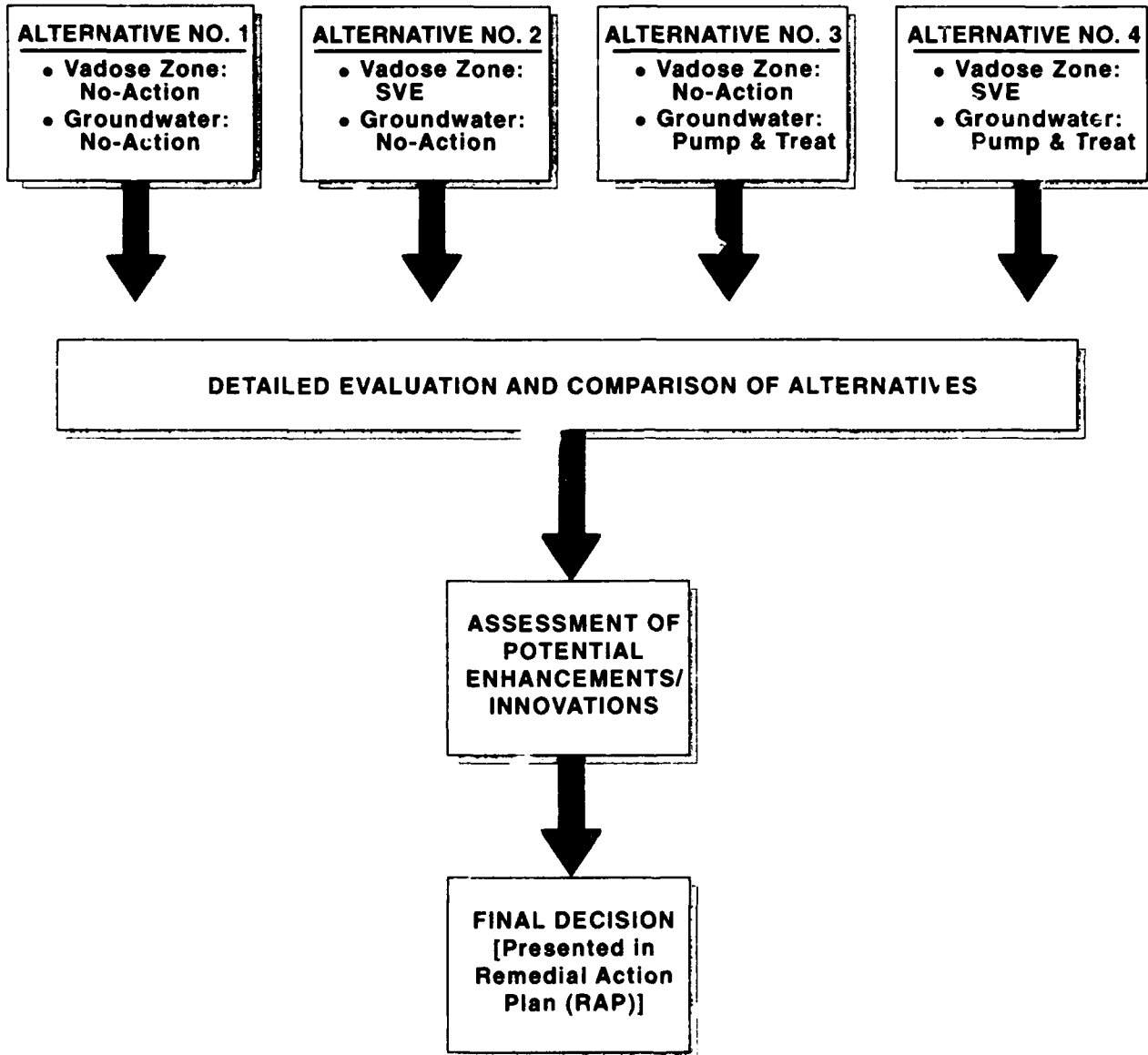


FIGURE 6-8
ALTERNATIVE SELECTION
DECISION PROCESS
DAVIS GLOBAL COMMUNICATIONS SITE
McCLELLAN AIR FORCE BASE
YOLO COUNTY, CALIFORNIA

Soil Vapor Extraction

Capture System: Network of SVE wells
Treatment System: Catalytic Oxidation
End-Use System: Discharge to Atmosphere

Groundwater Extraction

Capture System: Network of Extraction Wells (four wells for Target Volume 1; nine wells for Target Volume 2)
Treatment System: Conventional Advanced UV Oxidation
End-Use System: Irrigation and Reinjection

Other capture, treatment, or end-use systems may be used in the remedial action, but the above *representative* systems will be adequate for the purposes of the detailed evaluation and comparison of alternatives.

The expected effectiveness of the different alternatives and potential shortcomings of each alternative are compared in the detailed evaluation.

The last step between the detailed evaluation and the selection of a remedial action is the identification of potential innovations that might be effective at improving the remedial action. Currently, not enough data exist to justify performing a detailed analysis of such innovations. However, during the time period between the RI/FS and remedial action selection, data may become available that show a particular innovation to be a significant improvement over the current state-of-the-art. In this case, the decisionmakers may wish to modify the preferred alternative to incorporate the innovation. Potential innovations that might be applicable at the Davis Site are described in Section 6.4.

The detailed evaluation performed in this section is based on nine specific evaluation criteria cited in the *Guidance for Conducting Remedial Investigations and Feasibility Studies* (U.S. EPA, 1988). The nine criteria are listed below:

- Overall Protection of Human Health and Environment
- Compliance with ARARs
- Long-term Effectiveness and Permanence
- Reduction of Toxicity, Mobility, and Volume through Treatment
- Short-term Effectiveness
- Implementability
- Cost

- Community Acceptance
- State Acceptance

6.3.1 Overall Protection of Human Health and the Environment

Alternative 1 is the No-Action Alternative for both the vadose zone and the groundwater. It would not protect human health or the environment. Contamination that currently resides in the vadose zone would be allowed to continue to migrate downward into the groundwater. Vadose zone contaminant transport modeling (summarized in Appendix H) indicates that peak groundwater concentrations of PCE alone would be in excess of 20 to 80 µg/l for hundreds of years into the future because of the movement of contamination from the vadose zone into the groundwater.

Contamination that is already in the groundwater would remain in place under Alternative 1 and would migrate laterally away from the site and vertically into deeper aquifer systems, creating additional risks to human health and the environment.

Alternative 2 is the SVE Alternative for the vadose zone with no groundwater action. Alternative 2 effectively removes the long-term source of groundwater contamination by removing the contaminants in the vadose zone. However, the contamination currently in the groundwater would remain, where it could migrate laterally and vertically into aquifer systems that are currently uncontaminated. While this contamination currently poses no threat to human health, it has the potential to migrate into downgradient wells where exposure to humans would be possible.

Alternative 3 is the Groundwater Extraction Alternative with no vadose action. It would effectively contain the contamination as it enters the groundwater system and would prevent the contamination from spreading. By virtue of containing and treating the groundwater contamination, protection to human health and the environment would be provided with respect to groundwater exposure; however, the contamination would still remain in the vadose zone. VOC contamination could potentially pose a health risk via emissions to the air from the soil surface and inhalation exposure. However, a preliminary risk assessment performed for the Davis Site indicates that estimated risks associated with these exposure pathways fall below levels generally of concern to regulatory agencies (CH2M HILL, 1993a). Alternative 3 can therefore offer *overall* protection to human health and the environment, but would need to be operated over an extremely long period of time (greater than 200 years) to adequately capture the contamination that migrates from the vadose zone into the groundwater.

Alternative 4, SVE and Groundwater Extraction, is a combination of Alternatives 2 and 3. It also provides overall protection to human health and the environment. As with Alternative 3, the groundwater would be contained and treated. However, this alternative offers a significant advantage over Alternative 3 in that it also addresses the long-term source of groundwater contamination that resides in the vadose zone and would potentially avoid an extremely long time frame of operation.

Table 6-3 is a summary of the Overall Protection of Human Health and the Environment evaluation for the four alternatives.

Table 6-3 Overall Protection of Human Health and the Environment--Summary				
	Alternative 1 No-Action	Alternative 2 Soil Vapor Extraction	Alternative 3 Groundwater Extraction	Alternative 4 Soil Vapor and Ground- water Extraction
Alternative Protects Human Health			✓	✓
Alternative Protects the Environment			✓	✓

6.3.2 Compliance with ARARs

Alternative 1 would not comply with ARARs. The groundwater would continue to have contaminant concentrations significantly above background and far in excess of state and federal maximum contaminant levels (MCLs). Furthermore, because nothing would be done to address the long-term source of contamination (VOCs in the vadose zone), the groundwater concentrations would continue to exceed ARARs for an estimated period of 200 years or longer.

Alternative 2 also does not address groundwater contamination, and chemical-specific ARARs will not be met. This alternative targets the long-term source of contamination that resides in the vadose zone, but does nothing to reduce concentrations in the groundwater. Eventually, natural processes such as dilution or contaminant degradation would reduce groundwater concentrations over time, possibly to a point where they might comply with ARARs in the future. However, the time required to obtain such concentration reductions is difficult to know with reasonable certainty and may vary anywhere from a couple of years to several hundred years. The SVE system for Alternative 2 would be built and operated to comply with action-specific and location-specific ARARs.

Alternatives 3 and 4 would both be designed to meet all ARARs. Under these alternatives, contaminated groundwater would be captured and treated until chemical-specific ARARs are met. Both alternatives would be built and operated to comply with action-specific and location-specific ARARs.

Table 6-4 is a summary of the compliance with ARARs evaluation for the four alternatives.

Table 6-4 Compliance with ARARs--Summary				
	Alternative 1 No-Action	Alternative 2 Soil Vapor Extraction	Alternative 3 Groundwater Extraction	Alternative 4 Soil Vapor and Groundwater Extraction
Alternative can comply with chemical-specific ARARs			✓	✓
Alternative can comply with action-specific ARARs	Not Applicable	✓	✓	✓
Alternative can comply with location-specific ARARs	Not Applicable	✓	✓	✓

6.3.3 Long-Term Effectiveness and Permanence

Alternative 1 would not alter the threats posed by the vadose zone or groundwater contamination at the site. No controls would be placed on any of the contamination. Some natural attenuation of the contamination may occur through dispersion, dilution, or degradation, but the ability to accurately estimate these mechanisms is weak, and it cannot be assumed that this natural attenuation would occur before human or environmental exposures occur. In short, Alternative 1 does not provide an effective or permanent long-term solution to the contamination problem at the Davis Site.

SVE would be used in Alternative 2 to reduce VOC levels in the vadose zone. According to the modeling results presented in Appendix I, SVE would be able to reduce the in situ vadose zone contamination to levels that would be protective of human health and the environment within about 10 years. This alternative does nothing to address the groundwater concentrations.

Under Alternative 2, treatment residuals would be generated from the offgas treatment system. If catalytic oxidation is used as the offgas treatment method low levels of hydrochloric acid (HCl) would be produced in addition to water and carbon dioxide. Treatment evaluations presented in Appendix L suggest that the HCL emissions would be

approximately 0.5 pound/hour which should not pose a threat to human health or the environment.

Both the residual vadose zone VOC contamination and treatment residuals would be monitored under Alternative 2. SVMWs CH-1, CH-2, CH-3, CH-4, and CH-5 would provide in situ vapor monitoring points to confirm that at the end of remedial action VOC levels have been reduced below cleanup standards. Monitoring of the offgas would also be conducted to make sure that HCL levels are nonthreatening and that VOCs are not escaping untreated.

Groundwater extraction would be used under Alternative 3 to capture and treat the contaminated groundwater. Under this alternative, contaminants currently in the vadose zone would be allowed to migrate into the groundwater over a time frame on the order of 200 years, meaning that the groundwater extraction system would need to be operated over an extreme time span. Residual VOC contamination could potentially remain in the groundwater for centuries to come. It is therefore imperative that monitoring be adequate to make sure that the groundwater contamination is being captured. As described in Appendix J, water levels and water quality data are required during operation of the extraction system to check for adequate hydraulic containment and to check on improvements in water quality over time. The groundwater extraction procedures outlined in Appendix J would provide adequate long-term monitoring of the groundwater contamination.

Treatment of the groundwater under Alternative 3 will produce no appreciable treatment residuals.

Alternative 4 includes both soil vapor and groundwater extraction. The in situ vadose zone residuals described for Alternative 2 and the groundwater residuals described for Alternative 3 will also exist for this alternative. However, because the majority of the vadose zone contamination would not be allowed to become a long-term source of groundwater contamination, the groundwater residuals would probably exist on the order of 30 years rather than 200. A combination of the in situ monitoring methods from Alternatives 2 and 3 would be used for Alternative 4.

The treatment system for Alternative 4 will consist of an catalytic oxidation unit for the offgas, and a conventional advanced UV oxidation unit for the groundwater. The treatment residuals would be identical to those generated from Alternative 2 and would not be threatening to human health. Table 6-5 is a summary of the Long-Term Effectiveness and Permanence evaluation for the four alternatives.

Table 6-5**Long-Term Effectiveness and Permanence--Summary**

	Alternative 1 No-Action	Alternative 2 Soil Vapor Extraction	Alternative 3 Groundwater Extraction	Alternative 4 Soil Vapor and Groundwater Extraction
Treatment Residuals will be Rendered Harmless		✓	✓	✓
Long-Term Controls are Adequate and Reliable to Monitor Residual Contam- ination in the subsurface		✓	✓	✓
In Situ Residual Contamination will be Reduced to Levels Protective of Human Health and the Environment			✓	✓
Notes: Groundwater monitoring is assumed to continue if Alternative 2 is selected. Long-term groundwater monitoring may be required for excessive timeframe under Alternative 3 (200 years or longer).				

6.3.4 Reduction of Toxicity, Mobility, and Volume through Treatment

This criterion addresses the degree to which contamination is reduced in toxicity, mobility, or volume *through treatment*. The alternatives are evaluated against this criterion for two separate cases. First, are there reductions with respect to the contaminant that actually remain in the subsurface? Second, are there reductions with respect to the contaminants that have been removed from the ground and are now present in some form at the ground surface?

Alternative 1 invokes no treatment whatsoever and therefore does not reduce contaminant toxicity, mobility, or volume through treatment.

The SVE and treatment system proposed for Alternative 2 would impact contaminant toxicity, mobility, and volume. The subsurface vadose zone contamination would have its mobility controlled by the subsurface air-flow which would force the contamination to move towards the extraction wells; the toxicity, volume, and mass of vadose zone contamination would also be reduced because the SVE system physically removes the contaminants from the ground. Aboveground, the contaminants would

have their toxicity, mobility, and volume virtually eliminated by the thermally destructive nature of a CatOx oxidation offgas treatment system. The toxicity, mobility, and volume of contaminants in the groundwater would not be impacted by Alternative 2.

Extraction of groundwater only (Alternative 3) will physically capture the contamination in the groundwater target volume, reducing the subsurface toxicity, mobility, and volume *within the selected target volume*. If Target Volume 1 (B and C aquifers, A-B and B-C aquitards only) is selected, the low levels of contamination that currently reside deeper in the subsurface (C-D aquitard and deeper) will not be impacted by the action and will not experience reductions in toxicity, mobility, or volume, because they are not included in the target volume. If Target Volume 2 (all aquifers) is selected, nearly all of the contaminants will have decreases in toxicity, mobility, and volume. Aboveground, the toxicity, mobility, and volume will be virtually eliminated after the contaminated water passes through an advanced UV oxidation unit, which will destroy virtually all of the contaminants. Alternative 3 does nothing to address the toxicity, mobility, or volume of contaminants above the water table.

Alternative 4 addresses toxicity, mobility, and volume of contaminants above the water table as described for Alternative 2 and below the water table as described for Alternative 3. It is the most thorough alternative with respect to reducing toxicity, mobility, and volume.

Table 6-6 is a summary of the Reduction of Toxicity, Mobility, and Volume through Treatment evaluation for the four alternatives.

6.3.5 Short-Term Effectiveness

Since no remedial action occurs under Alternative 1 no short-term effects will occur that differ from the current condition.

Implementation of an SVE system (Alternative 2) will entail minimal construction-related risks since the extraction wells are already installed and a new drilling program is not required. There will still be some risks associated with the aboveground construction, but there is nothing anomalous with these risks. It is estimated that the SVE system will be able to remove the vadose zone contamination within 10 years. However, this alternative will never achieve the remedial response objectives at the site, because it fails to address the groundwater contamination.

Table 6-6 Reduction of Toxicity, Mobility, or Volume Through Treatment-Summary				
	Alternative 1 No-Action	Alternative 2 Soil Vapor Extraction	Alternative 3 Groundwater Extraction	Alternative 4 Soil Vapor and Groundwater Extraction
Toxicity of Contaminants Aboveground is Reduced		✓	✓	✓
Toxicity of Contaminants in Vadose Zone is Reduced		✓		✓
Toxicity of Contaminants in Groundwater is Reduced			✓	✓
Mobility of Contaminants Aboveground is Reduced		✓	✓	✓
Mobility of Contaminants in Vadose Zone is Reduced		✓		✓
Mobility of Contaminants in Groundwater is Reduced			✓	✓
Volume of Contaminants Aboveground is Reduced		✓	✓	✓
Volume of Contaminants in Vadose Zone is Reduced		✓		✓
Volume of Contaminants in Groundwater is Reduced			✓	✓

Alternative 3 (groundwater extraction) may include some construction-related risks depending on the selected target volume. If Target Volume 1 is selected, no additional drilling will be required because the extraction wells are already installed, and there will only be construction risks associated with the aboveground construction. Five new extraction wells will be required for Target Volume 2 to capture contamination in the deeper alluvial units. There would therefore be drilling related construction risks. However, with appropriate and readily available monitoring and protective equipment these risks should not be any greater

than those associated with drilling programs at uncontaminated sites. It is estimated that this alternative will take an extreme period of time to achieve remedial response objectives (200 years or longer) because infiltration of contaminants into the groundwater from the vadose zone will be allowed to continue until the contaminant mass from the vadose zone has been depleted.

The construction-related risk scenarios described for both Alternatives 2 and 3 apply to Alternative 4, which is basically a combination of Alternatives 2 and 3. It is estimated that remedial response objectives under this alternative could be achieved within a 30-year time frame.

All of the above alternatives (with the exception of Alternative 1) invoke some form of air or water treatment (which for the purposes of the detailed analysis is assumed to be catalytic oxidation for air and advanced UV oxidation for water). In addition, water discharges will comply with ARARs before being routed to the appropriate end use. There is a possibility that an offgas treatment system could fail, resulting in an untreated discharge of soil gas to the atmosphere. If this occurred, all remedial systems would be shut down immediately. Similarly, there is a possibility that a water treatment system could fail, allowing an untreated discharge of contaminated water. For this case, the groundwater extraction system would shut down.

Table 6-7 is a summary of the Short-Term Effectiveness evaluation for the alternatives.

6.3.6 Implementability

All of the alternatives are fully implementable at the Davis Site. The technologies are well proven, and no impediments to implementing the actions have been identified. SVE has been selected by the Environmental Protection Agency (EPA) to clean up VOCs from the vadose zone at 83 CERCLA sites nationwide, and groundwater extraction is a commonly used method to capture and remove contamination from the groundwater.

The equipment and specialists needed to implement the alternatives are expected to be readily available. The Davis Site is located near the greater Sacramento metropolitan area, which should be able to provide most of the resources needed.

Table 6-7 Short-Term Effectiveness-Summary				
	Alternative 1 No-Action	Alternative 2 Soil Vapor Extraction	Alternative 3 Groundwater Extraction	Alternative 4 Soil Vapor and Groundwater Extraction
Community will be Protected during Implementation of Remedial Action		✓	✓	✓
Workers will be Protected during Implementation of Remedial Action		✓	✓	✓
Alternative can Comply with Air Quality Standards		✓	✓	✓
Environmental Impacts during Construction will be in Compliance with Regulations	Not Applicable	✓	✓	✓
Remedial Response Objectives Achievable within an Acceptable Timeframe				✓

Table 6-8 summarizes the implementability evaluation for the four alternatives.

Table 6-8 Implementability-Summary				
	Alternative 1 No-Action	Alternative 2 Soil Vapor Extraction	Alternative 3 Groundwater Extraction	Alternative 4 Soil Vapor and Groundwater Extraction
Technology can be Constructed at the Davis Site	Not Applicable	✓	✓	✓
Technology is Well Proven and Reliable	Not Applicable	✓	✓	✓
Technology can be Adequately Monitored	Not Applicable	✓	✓	✓
Adequate Treatment, Storage Capacity, and Disposal Services are Available	Not Applicable	✓	✓	✓
Necessary Equipment and Specialists are Available	Not Applicable	✓	✓	✓

6.3.7 Cost

Feasibility study cost estimates are projected on the basis of the total costs of the remedial alternative for the duration of the alternative. Usually feasibility level cost estimates have an order-of-magnitude level of accuracy of approximately +50 to -30 percent. However, in this RI/FS there is a significant body of data to support the cost estimate. For example, four groundwater extraction wells have already been installed at the site at a known cost. The cost estimate for additional well installations at the Davis Site will be based in large part on these actual costs and will be more accurate than +50 to -30 percent. Other aspects of the cost estimate will not have the benefit of such recent site-specific data; for example, the cost of installing the network of groundwater pipelines needed to route water to and from the treatment facility may vary significantly, depending on the number and size of obstructions encountered (e.g., underground utilities or large concrete rubble) when excavating the pipeline ditches. For the case of pipelines, the cost estimate may at best be considered +50 to -30 percent. Overall it is anticipated that the cost estimates presented herein are slightly more accurate than +50 to -30 percent and are probably more along the lines of +30 to -30 percent. This +30 to -30 percent cost estimate level of accuracy should be used when planning for funds for the selected remedial action.

In addition to standard capital and operation and maintenance costs, the cost estimate also includes a variety of contingencies and other fees. A *contractor's operational contingency* of 5 percent of equipment capital cost is included to cover equipment, materials, and labor needed for construction items that cannot be detailed at this level of estimating. A *bid contingency* of 10 percent of construction cost is included to cover unknown costs associated with constructing the alternative, such as weather conditions, strikes by material suppliers, geotechnical unknowns, and unfavorable market conditions. *Permitting and legal fees* are estimated at 2 percent of total construction cost to obtain licenses and permits needed to construct and implement the selected alternative. *Services during construction* including construction management and engineering services are estimated at 8.5 percent of the total construction cost. *Engineering design costs* including design and process development, preparation of specifications and bid documents, drafting, and monitoring and testing are estimated at 15 percent of the total implementation cost.

Table 6-9 summarizes the cost estimates for each alternative. A brief synopsis of cost estimate assumptions for each line item are provided in the table. Capital and O&M costs shown in Table 6-9 are based on 1993 fiscal year dollars. However, none of the alternatives are expected to begin construction until 1995. Appended to the end of Table 6-9 is an estimate of capital and O&M costs in 1995 dollars assuming costs increase at a rate of 5 percent per year. Refer to Appendix M(a) for more cost detail on groundwater wells, pumps, piping and end use; Appendix M(b) provides cost details for the groundwater treatment system; Appendix I provides the cost details for the SVE extraction system installation and operation; and Appendix L should be referenced for cost details on the offgas treatment system.

Table 6-9 Cost Comparison for the Different Alternatives						
Item	Cost Assumptions	Alternative 2 (SVE Only)	Alternative 3 (Groundwater Extraction Only)		Alternative 4 (SVE and Groundwater Extraction Only)	
			Target Zone 1	Target Zone 2	Target Zone 1	Target Zone 2
Capital Outlays						
GW Extraction Wells	No new wells are needed for Target Zone 1. Five new wells are needed for Target Zone 2 (3 @ 200 ft. depth; 2 @ 240 ft depth). New wells are 6 inches in diameter with 20 to 30 ft. ss screen interval. Installed using arch drilling method. Cost estimated @ \$120.00/foot.	\$0	\$0	\$130,000	\$0	\$130,000
Extraction Well Pipelines	Refer to Appendix M(b) for pipeline cost assumptions.	\$0	\$28,000	\$40,000	\$28,000	\$40,000
GW Reinjection Wells	Wells are 8 inches in diameter with coated steel casing and ss screen. Installed using mud rotary drilling method. Refer to Appendix M(b) for details.	\$0	\$126,000	\$168,000	\$126,000	\$168,000
Submersible Pumps	No new pumps are needed for Target Zone 1. Three new 7.5-hp pumps and two new 10-hp pumps are needed for Target Zone 2.	\$0	\$0	\$5,000	\$0	\$5,000
GW Monitoring Wells	One new monitoring well is needed for Target Zone 2 only (@ 240 feet deep @ \$100.00 per foot).	\$0	\$0	\$24,000	\$0	\$24,000
End-use system pipelines	The pipelines that connect the treatment plant to the point of end-use are 4,400 feet of pipe at \$27 per foot for Target Zone 1 and 4,400 feet of pipe at \$45 per foot for Target Zone 2.	\$0	\$119,000	\$198,000	\$119,000	\$198,000
GW Pump Station	Pump station costs are based on previous experience. See Appendix M(b) for details.	\$0	\$23,000	\$23,000	\$23,000	\$23,000
GW Treatment System	The advanced ultraviolet oxidation system is designed to treat flow rates of 380 gpm for Target Zone 1 and 820 gpm for Target Zone 2. Costs are based on vendor quotes. See Appendix M(a) for detail.	\$0	\$290,000	\$470,000	\$290,000	\$470,000
GW Discharge Structures	Discharge structure costs are based on previous experience. See Appendix M(b) for details.	\$0	\$10,000	\$10,000	\$10,000	\$10,000
Telemetry	Telemetry costs are based on previous experience. See Appendix M(b) for detail.	\$0	\$40,000	\$40,000	\$40,000	\$40,000
Vapor Extraction Wells	No new vapor extraction wells are required.	\$0	\$0	\$0	\$0	\$0
Vapor Monitoring Wells	No new vapor monitoring wells are required.	\$0	\$0	\$0	\$0	\$0
Vacuum Blowers	Four new explosion-proof 2-hp blowers are needed, with associated electrical controls and housing unit. Refer to Appendix I for detail.	\$21,000	\$0	\$0	\$21,000	\$21,000

Table 6-9 Cost Comparison for the Different Alternatives						
Item	Cost Assumptions	Alternative 2 (SVE Only)	Alternative 3 (Groundwater Extraction Only)		Alternative 4 (SVE and Groundwater Extraction Only)	
			Target Zone 1	Target Zone 2	Target Zone 1	Target Zone 2
Pipelines for the SVE System	Refer to Appendix I for pipeline cost details.	\$32,000	\$0	\$0	\$32,000	\$32,000
Offgas Treatment System	The catalytic oxidation offgas treatment unit is capable of treating 200 scfm of contaminated air. Cost is estimated at \$67,000. See Appendix I for details.	\$67,000	\$0	\$0	\$67,000	\$67,000
Subtotal		\$120,000	\$636,000	\$1,108,000	\$756,000	\$1,228,000
Contractors Operational	5 percent of Construction Estimate.	\$6,000	\$31,800	\$55,400	\$37,800	\$61,400
Construction Cost Subtotal		\$126,000	\$667,800	\$1,163,400	\$793,800	\$1,289,400
Bid Contingencies	10 percent of Construction Cost.	\$12,600	\$66,780	\$116,340	\$79,380	\$128,940
Total Construction		\$138,600	\$734,580	\$1,279,740	\$873,180	\$1,418,340
Permitting and Legal	2 percent of Total Construction.	\$2,772	\$14,692	\$25,595	\$17,464	\$28,367
Services During Construction	8.5 percent of Total Construction.	\$11,781	\$62,439	\$108,778	\$74,220	\$120,559
Total Implementation Cost		\$153,153	\$811,711	\$1,414,113	\$964,864	\$1,567,266
Engineering Design Cost	15 percent of Total Implementation Cost.	\$22,973	\$121,757	\$212,117	\$144,730	\$235,090
Total Capital Cost		\$176,126	\$933,468	\$1,626,230	\$1,109,593	\$1,802,356
Annual O & M						
GW Extraction System	See Appendix M(b), Table M(b)-10 for cost details.	\$0	\$41,700	\$51,500	\$41,700	\$51,500
GW Remediation System	See Appendix M(b), Table M(b)-10 for cost details.	\$0	\$53,900	\$67,400	\$53,900	\$67,400
GW Irrigation System	See Appendix M(b), Table M(b)-10 for cost details.	\$0	\$5,700	\$5,800	\$5,700	\$5,800
GW Treatment System	Costs are based on labor, power, lab analytical, health and safety, and maintenance contingency. See Appendix M(a) for detail.	\$0	\$251,000	\$308,000	\$251,000	\$308,000
Vapor Extraction System	See Appendix I for cost details (20 to 30 percent for maintenance, \$2,000 for power).	\$25,000			\$25,000	\$25,000
Offgas Treatment System.	Estimate includes labor, materials, and power. See Appendix I for details.	\$28,000			\$28,000	\$28,000
Total O&M		\$53,000	\$352,300	\$522,700	\$405,300	\$575,700
Capital Cost (1995 dollars)		\$194,000	\$1,030,000	\$1,767,000	\$1,224,000	\$1,961,000
O&M Cost (1995 dollars)		\$59,000	\$388,000	\$576,000	\$447,000	\$635,000

Note:
A carbon treatment unit may be required to be installed downstream of the groundwater treatment facility as a backup polishing unit.
The costs associated with this unit have not been included in this cost analysis.

The costs may be expressed in terms of present worth or on an annualized basis. Figures 6-9 and 6-10 compare the costs of alternatives in graphical form. Alternative 1 is not shown because it incurs no cost at all. As expected Alternative 4 is the most expensive option, but is also the most protective because it is the only alternative that targets contamination that resides in the vadose zone and the groundwater.

6.3.8 Community Acceptance

Alternative 1 would probably not be accepted by the community. Community members are expected to prefer alternatives that remove contaminants from their locale. The acceptance by the community of the other alternatives is difficult to assess at this time, but will be made clear during the public comment period, during which time community members will be invited to comment on this report. Community acceptance will be more fully addressed in the remedial action plan (RAP) for the Davis Site.

6.3.9 State Acceptance

Where possible, the state is expected to prefer alternatives that reduce subsurface contamination to levels at or below background. State acceptance will be more fully addressed in the RAP, after public comment has been received on this RI/FS report.

6.4 Potential Innovations for the Alternatives

The technologies proposed in this report for the various alternatives being considered for the Davis Site are generally well proven and tested so that there is reasonable assurance that, if implemented properly, they will work. There is another class of "innovative technologies" that could in the future be used as part of the Davis remedial action. Today, these innovations are not proven enough to justify performing a detailed evaluation of them. However, treatability data may become available in the near future that indicates that they should in fact be used at the Davis Site. This section provides brief descriptions of the current state-of-the-art of innovations that show particular promise for potential implementation at the Davis Site, namely *Electron Beam Technology* to treat contaminated offgas, various *Emerging Advanced UV Oxidation Enhancements* to treat contaminated water streams, and *Dual-Phase Extraction* to improve the capture and removal of subsurface contamination. Table 6-10 summarizes major studies currently being conducted for each of these technologies. The results of these and other studies like them should be monitored to help evaluate the benefits that a given enhancement may have for the Davis Site remediation.

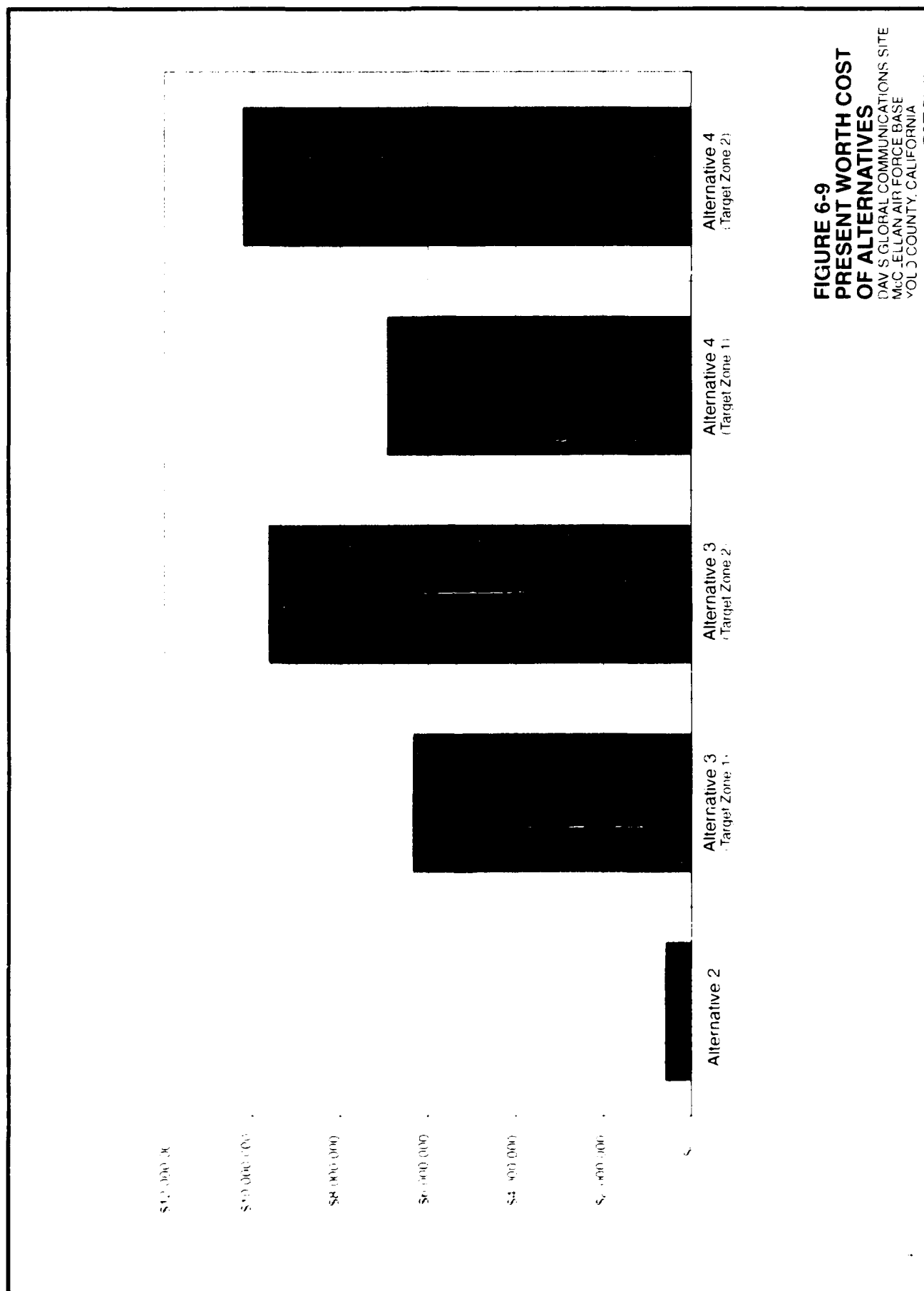
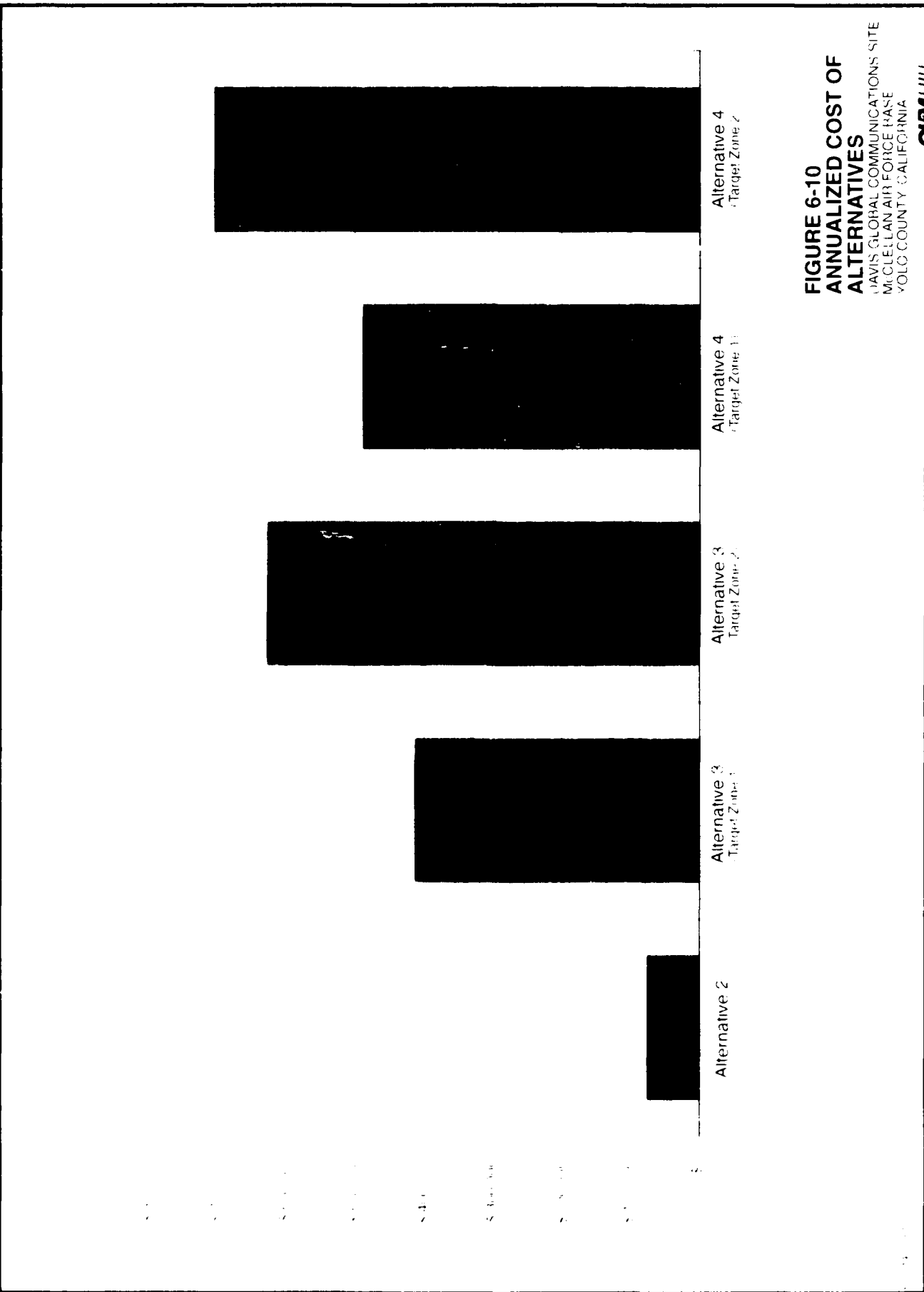


FIGURE 6-9
PRESENT WORTH COST
OF ALTERNATIVES
 DAVIS GLOBAL COMMUNICATIONS SITE
 MCCLELLAN AIR FORCE BASE
 YOLO COUNTY, CALIFORNIA



**FIGURE 6-10
ANNUALIZED COST OF
ALTERNATIVES**
JAVIS GLOBAL COMMUNICATIONS SITE
MCQUELAN AIR FORCE BASE
YOLO COUNTY, CALIFORNIA

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Table 6-10 Information Sources for Various Remediation Enhancements		
Innovation	Media Affected	Major Reference(s)
Electron Beam Technology	Contaminated airstream extracted from the subsurface	ZAPIT Company (Contact: Dr. Peter Schonberg, 408/986-1700).
Enhancements to Conventional Advanced UV Oxidation	Contaminated water stream extracted from subsurface	Many references, see for example, Table 6-11.
Dual-Phase Extraction	Contamination that resides in a zone of seasonal water table fluctuation	Xerox Co. case study, Building 209, Webster New York. Enhanced Groundwater Extraction Utilizing Innovative Technology: "HIVAC" Woodward-Clyde Consultants. Presented at the November 1990 Hazardous Materials Management Conference.

6.4.1 Treatment Innovations

Potential treatment innovations exist for both contaminated air and contaminated water streams. For contaminated air, electron beam technology (EBT) is a promising innovation. EBT uses a high energy beam of electrons through which the contaminated airstream must pass. The electrons release concentrated pockets of energy into the gas stream, creating free radicals such as hydroxyl and hydrogen radicals. These radicals initiate a series of chain reactions that oxidize the contaminants. The oxidation reactions in an EBT system occur at near ambient temperature and pressure. Bench scale studies of EBT indicate a wide range of destruction removal efficiencies, ranging anywhere from 60 percent to 99 percent. In addition, testing to date indicates that EBT does not effectively remove 1,1,1-trichloroethane (TCA) or Freon 113. Tests show that by adding oxidants to the EBT system destruction removal efficiencies can be improved. However, the magnitude of improvement that these oxidants have on the EBT system performance has not yet been fully quantified.

For contaminated water, there are a variety of innovative enhancements to the conventional advanced UV oxidation system. These enhancements are in various stages of development and progress on them should be monitored at least quarterly so that the decisionmakers can have early access to a better technology as soon as it has demonstrated effectiveness. Table 6-11 summarizes some of the main emerging technologies that will potentially enhance the performance of an advanced UV oxidation treatment system.

Table 6-11 Emerging Technological Enhancements to Conventional UV Oxidation					
Emerging Technology Name	Technology Description	Stage of Development	Vendor	Phone Number	
Laser Induced Photochemical Oxidative Destruction (LIPOD)	Photochemical oxidation of organic compounds in wastewater using a chemical oxidant and ultraviolet radiation from an Excimer laser. Does not perform well with turbid water.	Research stage	Energy and Environmental Engineering, Inc. (contact: James Porter)	(617) 666-5500	
Cavitation/UV Radiation (CAV-OX)	Groundwater treated for presence of organics by a combination of enclosed cavitation, UV exposure and H2O2 oxidation. Does not perform well with turbid water.	Research Stage	Magnum Water Technology (contact: Jack Simser)	(310) 322-4143	
Photothermal Detoxification Unit	The photothermal detoxification unit uses photothermal reactions conducted at temperatures between 200 to 500 degrees C. Reaction rates are increased due to photolytic oxidation by UV and higher temperatures. Pilot tested.	Some Pilot Testing Completed	University of Dayton Research Institute (contact: Barry Dellinger)	(513) 229-2846	
Pulsed UV Lamp (Wekhof Process)	The Wekhof Process is a patented pulsed UV flashlamp that destroys organics by photolysis. Produces wavelengths across the full UV spectrum, overlaps critical wavelengths for all organics. Can be used in conjunction with H2O2 or TiO2 catalyst.	Research Stage	Purus, Inc.	(408) 453-7804	

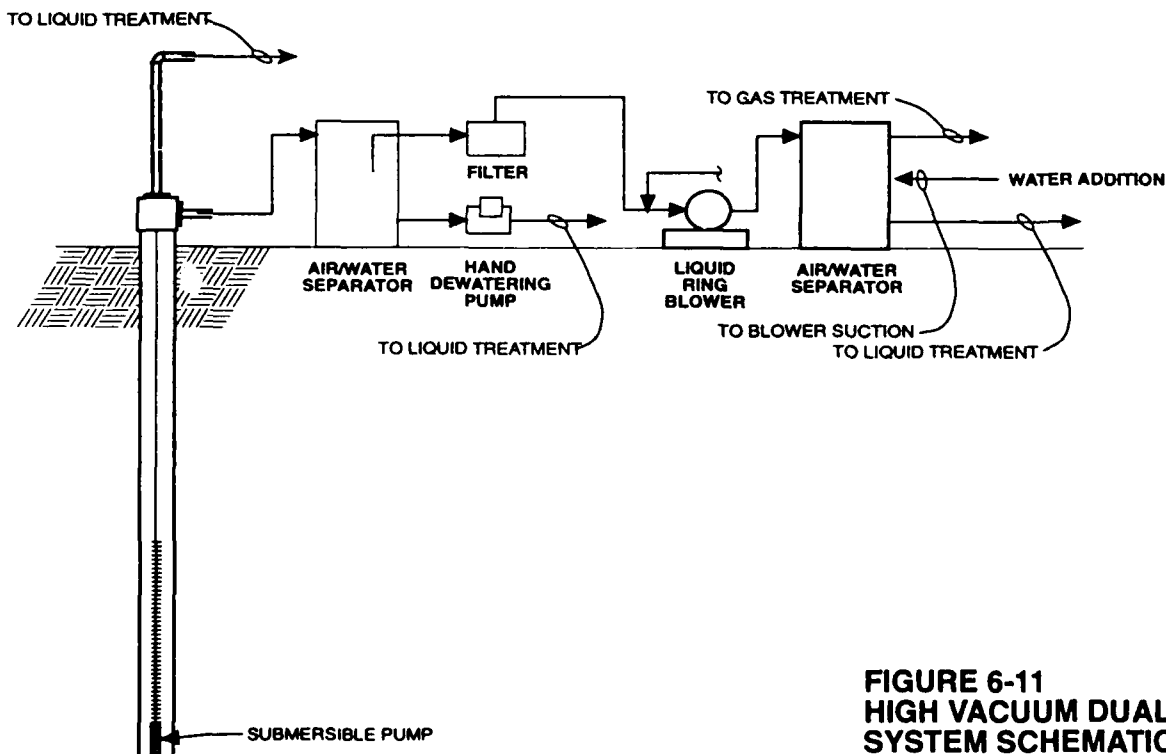
6.4.2 The Dual-Phase Extraction Innovation

Dual-phase extraction is a method by which contaminated air and water is removed from the subsurface from the same well. At the Davis Site, dual-phase extraction could be a viable technique to remove contamination from the zone of seasonal water table fluctuation located at a depth range of approximately 40 to 70 feet bgs.

The possible applicability of dual-phase extraction is based on subsurface characteristics that may make conventional groundwater extraction or SVE difficult to implement. The soils in this depth interval are of a fine-grained nature and likely have low hydraulic conductivities, making removal via groundwater pumping difficult during the times that the zone is saturated. In addition, the seasonal wetting of the fine-grained soil is likely to maintain high levels of water saturation that will create low air permeabilities that may make standard SVE operation ineffective.

Dual-phase extraction provides a possible method of removing contaminated groundwater from the zone of seasonal water table fluctuation and also improving the airflow characteristics of the soil so that contaminated air can be more effectively withdrawn from the zone. Appendix O, Evaluation of Dual-Phase Extraction, provides a detailed description and evaluation of dual-phase extraction. The system evaluated for the Davis Site will consist of a downhole submersible pump coupled with an above-ground high vacuum liquid ring blower, as illustrated in Figure 6-11.

The possible applicability of dual-phase extraction for the zone of seasonal water table fluctuation is based on subsurface characteristics that may make conventional groundwater extraction or SVE difficult.



**FIGURE 6-11
HIGH VACUUM DUAL-PHASE
SYSTEM SCHEMATIC**

The theory of dual-phase operation is that the submersible pump would be used to desaturate the zone and to keep the water table depressed.

The high vacuum blower would be used to apply a vacuum, which would dry out a zone of soil near the well until the water content is reduced below the soil's shrinkage limit. Shrinkage cracks would then form allowing for improved withdrawal of contaminated air. Refer to Appendix O, Figure O-2.

Before this system can be considered for development at the Davis Site two things must happen. First, additional data need to be collected to better characterize the soil gas mass and distribution within the zone of seasonal water table fluctuation. This will help optimize the number and locations of the extraction wells. Appendix O provides recommended sampling locations. Second, pilot testing should be conducted to evaluate the degree to which an applied high vacuum can achieve improved airflow through the targeted zone. Pilot testing should be done at different locations to provide an estimate of the lateral variability in soil properties. Appendix O provides details on the proposed pilot testing for dual-phase extraction. If pilot testing shows dual-phase extraction to be an effective technique for removing contamination, the system should be given serious consideration for implementation at the Davis Site.

6.5 Contingency Planning to Address Uncertainty

The four alternatives that have been developed in this chapter were evaluated and compared using data from RI activities that have occurred at the Davis Site. There are areas of uncertainty regarding the nature and extent of contamination, and decisions on remedial action will need to be made in the face of these uncertainties.

Major sources of uncertainty for the Davis Site include aquifer properties, groundwater flow characteristics, unit target volumes, and the mass of contamination in the subsurface. Each of these uncertainties has the potential to increase the scope and the cost of the alternatives evaluated in this FS. An assessment of how the alternatives could be impacted by these uncertainties is provided in this section.

6.5.1 Impact of Uncertainties on the Remedial Action Alternatives

6.5.1.1 Aquifer Properties

Aquifer properties are one source of uncertainty for the Davis Site. Transmissivity of the aquifers, storativity of the aquifers, and vertical permeability of the aquitards have the largest impact on the alternatives.

Transmissivity was estimated using data from 5 aquifer tests and 11 short duration development tests. Ranges of transmissivity used for this report are presented in Table 6-12. If the transmissivities are lower than the ranges cited in the table, additional extraction wells may be needed to attain groundwater capture. This is because the areal extent of capture from a single well decreases with decreasing transmissivity (Freeze & Cherry, 1979).

Table 6-12 Impact of Uncertainties on the Remedial Action Alternatives			
Subsurface Characteristic	Assumed Value of the Characteristic for the RI/FS Report	Uncertainties Inherent in Using the Assumed Value	Potential Impact of the Uncertainties on the Remedial Action Alternatives
Aquifer Properties			
Aquifer Transmissivity (B, C, D, E aquifers)	B: 100 - 1000 sq. ft. per day C: 1000 - 3000 sq. ft. per day D: 1000 - 1000 sq. ft. per day E: 1000 - 7000 sq. ft. per day	5 aquifer tests and 11 short duration pump tests were performed to develop reasonable ranges of transmissivities (T). However, the soils have shown significant heterogeneities; there may be local areas where the T's are outside the assumed range.	If the transmissivities are lower than the expected range, more extraction wells will be needed to capture the water.
Aquifer Storage Coefficient (B, C, D, E aquifers)	B: 0.1 - 0.001 C: 0.00007 D: 0.002 - 0.0001 E: 0.0002 - 0.0001 (based on D aquifer results)	5 aquifer tests and 11 short duration pump tests were performed to develop reasonable ranges of storativity (S). However, the soils have shown significant heterogeneities; there may be local areas where the S's are outside the assumed range.	If S is lower than the assumed ranges, then additional extraction wells may be needed or clean-up times may be increased. The E aquifer is the most uncertain with respect to storativity.
Aquiclude Vertical Permeability (B-C, C-D, D-E aquicludes)	B-C: 0.67 ft per day C-D: 0.025 ft per day D-E: 0.017 ft per day	Aquiclude properties were not measured. The value of vertical permeability used in the modeling was based on the observed soil type during drilling. The actual value will vary depending on the aquiclude soil types, and the "leakiness" of each aquiclude.	If aquiclude vertical permeability is lower than the assumed ranges, additional time may be required to remove contamination from the aquicludes.
Groundwater Flow Characteristics			
Horizontal Flow Gradients (B, C, D, E aquifers)	GW flow directions vary seasonally in magnitude and direction	Horizontal gradients are based on a 1-year sampling period from July 1992 to July 1993. Flows vary year to year and a 1-year of sampling does not represent the entirety of flow conditions at the Davis site; deviations from the assumed flows will occur.	If horizontal flow gradients are higher than the ranges used in the groundwater modeling, additional water extraction may be required. This can be accomplished through new extraction wells, or higher extraction rates from existing wells.
Vertical Flow Gradients (B, C, D, E aquifers)	Flow directions vary from upward in the summer to downward in the winter (refer to figure 3-4)	Vertical gradients are based on 1-year of continuous data from a monitoring well cluster. Flows vary year to year and 1-year of sampling does not represent the entirety of flow conditions at the Davis site; deviations from the assumed flows will occur.	If downward vertical gradients are higher than those used in the modeling, additional extraction may be needed to capture the water. This can be accomplished through new extraction wells, or higher extraction rates from existing wells.

Table 6-12 Impact of Uncertainties on the Remedial Action Alternatives			
Subsurface Characteristic	Assumed Value of the Characteristic for the RI/FS Report	Uncertainties Inherent in Using the Assumed Value	Potential Impact of the Uncertainties on the Remedial Action Alternatives
Unit Target Volumes			
Groundwater Unit Target Volumes (B,C,D,E aquifers)	B: 40,700,000 gal. C: 56,800,000 gal. D: 76,100,000 gal. E: 74,600,000 gal.	Unit Target volumes (UTVs) for the B & C aquifers are based on data from a large number of wells. These UTVs are not likely to change significantly. The D & E UTVs are less certain. UTVs will be reduced across the board if an MCL TV is selected.	Current target volumes are based on background. If an MCL-based UTV is selected, no E-aquifer extraction wells will be needed and extraction wells in the other aquifers will be reduced by two-thirds.
Vadose Zone Unit Target Volumes	2,100,000 cu. ft.	The vadose zone UTV is defined based on a shallow soil gas survey and 5 soil vapor monitoring wells. It is not expected to change significantly.	The vadose zone UTV is well defined, and shouldn't change significantly enough to impact the SVE system.
Mass of Contamination			
Mass of Contamination in Groundwater Aquifers (B,C,D,E)	B: 81.7 kg (180 lb.) C: 33.8 kg (74 lb.) D: 16 kg (35 lb.) E: 13 kg (29 lb.)	Uncertainty is created by using estimates of aquifer/contaminant properties, and by assuming point data from wells apply to polygon areas. The percentage of mass within each zone is reasonably accurate; the actual mass may differ from the estimates.	If masses are higher than currently estimated, the groundwater treatment system may incur higher O&M costs.
Mass of Contamination in Groundwater Aquitards (A, B, B-C, C-D, D-E)	A: 63.5 kg (140 lb.) B-C: 52.2 kg (115 lb.) C-D: 25.4 kg (56 lb.) D-E: 7.1 kg (16 lb.)	Actual contaminant data from the aquitards was not obtained. Contaminant concentrations were estimated using the average of aqueous concentrations from above and below each aquitard. The aquitard mass estimate is highly uncertain.	If aquitard masses are higher than currently estimated, the groundwater extraction system may need a longer operating time.
Mass of Contamination in Vadose Zone	45 kg (99 lb.)	Uncertainty is created by using estimates of vadose zone/contaminant properties, and by assuming point data from shallow soil gas samples and SVMWs apply to polygon areas.	If vadose zone masses are higher than currently predicted, the treatment unit may need to be modified to reduce HCl emissions.

Ranges of storativity used in this report are also presented in Table 6-12. These values were also estimated from the 5 aquifer and 11 short duration development tests. If storativity values fall below the ranges cited, additional extraction wells may be needed, or cleanup times may be longer than expected. Storativity is the volume of water that an aquifer releases from storage per unit surface area of aquifer per unit decline in hydraulic head. At steady state, drawdown ceases, and the storativity becomes relatively unimportant. However, groundwater modeling for the Davis site indicates that steady state will not be achieved during groundwater extraction for a long time period (>10 years). Therefore, storativity is a significant aquifer property that will impact groundwater remedial actions.

Representative data on the vertical permeability of the aquitards were not obtained for this report. Laboratory permeability testing on aquitard material was performed by ITC (1991), but these values are thought to be too low and do not take into account the macrostructure of the aquitards. Values of aquitard vertical permeability that were used to support the analysis of alternatives are summarized in Table 6-12. If the actual vertical permeabilities are lower than those cited, additional extraction time may be needed to remove contamination from the aquitards.

6.5.1.2 *Groundwater Flow Characteristics*

The magnitude and direction of groundwater flow is another source of uncertainty at the Davis Site. Horizontal and vertical flow gradients used in this report were primarily based on last year's data (July 1992 through July 1993). Groundwater flows inevitably vary from year to year, and conditions that deviate slightly from those used in this report should not be surprising. If horizontal or vertical gradient are steeper than those used in the groundwater modeling, additional extraction wells may be needed to capture the target area.

6.5.1.3 *Unit Target Volume (UTV)*

UTVs were defined previously in Chapter 4 as the volume of air or water within a specified three-dimensional target zone. The UTVs for the B and C aquifers are based on data from a large number of monitoring wells and will likely not change significantly. The UTVs for the D and E aquifers are less certain, but for contingency planning purposes can probably be assumed to be fixed.

The major uncertainty with respect to UTVs comes not from our understanding of the subsurface conditions; rather, the major uncertainty is derived from decisions that may be made by McClellan AFB and the regulatory agencies. If the decision is made to use target volumes based on maximum contaminant levels (MCLs) rather than background, the UTVs in the B, C, and D aquifers will be reduced in size by approximately two-thirds, and the E aquifer target volume would disappear altogether. This translates into fewer extraction wells and lower costs. Further discussion on the impact on using MCL-based target volumes is presented in Section 6.5.3, *Impact of Target Volume Changes on the Cost of Alternatives*.

6.5.1.4 Mass of Contamination

The mass estimates for the vadose zone and groundwater are uncertain for a variety of reasons, including assignment of contaminant concentration data from wells and shallow soil gas surveys to representative polygons (see Appendix F) and the use of soil properties (e.g., bulk density, porosity, organic content) in the mass calculations based on limited soils data.

The mass of contamination in the aquitards is particularly uncertain because no contaminant concentration data are available. The aquitard mass estimates used the additional assumption that the contaminant concentration can be approximated by the average of the aqueous concentrations above and below the aquitard.

For the vadose zone, if masses are significantly higher than those estimated an HCl scrubber may be required. Such a scrubber has the potential to add an additional \$150,000 to the capital cost of the alternatives that involve soil vapor extraction. For the groundwater, higher masses will entail higher O&M costs of the groundwater treatment system. These costs were factored into the original treatment costs summarized in Table 6-9 through the use of a 20 percent O&M contingency and will not be added to in this section.

6.5.2 Impact of Scope Changes on the Cost of the Alternatives

As previously discussed, there are four main areas of uncertainty that may impact the scope of the alternatives. Reasonable scope increases that can be attributed to each area of uncertainty were developed for planning purposes.

Table 6-13 is a summary of the assumed scope increase and the associated increase in cost for each alternative. As shown, the potential scope changes create increases in capital cost that range from 18 to 36 percent for Alternatives 3 and 4. Alternative 2 is more sensitive to potential scope changes because of the large increased cost that would be incurred if an HCl scrubber is required to treat the offgas.

6.5.3 Impact of Target Volume Changes on the Cost of Alternatives

The target volumes that are based on capturing the contamination that exceeds background levels are probably not subject to significant change. However, should a decision be made to establish target volumes using a different cleanup level (e.g., capture of contamination that exceeds MCLs), the target volumes may decrease in size dramatically.

MCL-based target volumes are approximately one-third the size of the background-based target volumes. This translates into significant cost savings if the decision is made to use MCL-based target volumes. Table 6-14 is a summary of the potential savings for an MCL-based

Table 6-13

Potential Impact of Scope Changes on the Cost of the Alternatives

Area of Uncertainty	Potential Impact on the Scope of Alternatives	Additional Contingency Costs			
		Alternative 2	Alternative 3	Alternative 4	
		Target Volume	Target Volume	Target Volume 1	Target Volume 2
Aquifer Properties	Two additional extraction wells needed for E aquifer (240 ft depth); 1 new well for each of the B, C, and D aquifers (450 ft. total depth). Well costs estimated at \$120 per foot. Pipeline costs increase by 30 percent.	no impact	\$62,000	\$124,000	\$62,000
Target Areas	Target areas are generally well defined and are not expected to change significantly. However, if the decision is made to use an MCL-based target area rather than a background-based target, area the scope of the work will be reduced (see Table 6-14).	no impact	no impact	no impact	no impact
Groundwater Flow Characteristics	One new well for each aquifer unit is included to account for larger than expected flow gradients. Well costs estimated at \$120 per foot; pipeline costs increase by 30 percent.	no impact	\$62,000	\$95,000	\$95,000
Mass of Contamination	HCl scrubber may be needed if the mass in the vadose zone is significantly higher than estimated (scrubber cost estimate @ \$150,000). Higher mass in groundwater will increase O&M costs of treatment into the original cost estimate (Table 6-9).	\$150,000	no impact	no impact	\$150,000
Subtotal Construction Cost without Scope Contingencies		\$120,000	\$649,000	\$1,216,000	\$769,000
Subtotal Construction Cost with Scope Contingencies		\$270,000	\$773,000	\$1,435,000	\$1,043,000
Contractors Operations (5% of construction)		\$14,000	\$39,000	\$72,000	\$53,000
Construction Cost Subtotal		\$284,000	\$812,000	\$1,507,000	\$1,096,000
Bid Contingency (10% of construction cost)		\$29,000	\$82,000	\$151,000	\$110,000
Total Construction		\$313,000	\$894,000	\$1,658,000	\$1,206,000
Permitting and Legal (2% of total construction)		\$7,000	\$18,000	\$34,000	\$25,000
Services during construction (8.5% of total construction)		\$27,000	\$76,000	\$141,000	\$103,000
Total Implementation Cost		\$347,000	\$988,000	\$1,833,000	\$1,334,000
Engineering Design Cost (8.5% of total implementation)		\$30,000	\$84,000	\$156,000	\$114,000
Total Capital Cost including Scope Contingencies		\$377,000	\$1,072,000	\$1,989,000	\$1,448,000
Total Capital Cost without Scope Contingencies		\$166,171	\$898,708	\$1,683,866	\$1,064,879
Percentage Increase in Total Capital Costs due to Scope Contingencies		127%	19%	18%	36%
					28%

Table 6-14 Impact of Target Area Changes on the Cost Alternatives						
Basis for Target Volume Selection	Cost Assumptions	Estimated Costs of Alternatives				
		Alternative 2 (SVE Only)	Alternative 3 (Groundwater Extraction Only)		Alternative 4 (SVE and Groundwater Extraction)	
			Target Volume 1	Target Volume 2	Target Volume 1	Target Volume 2
Capture of contamination that exceeds MCLs	Target areas are one-third the size of the background- based target areas. The E-aquifer requires no action. Only 2 D-aquifer extraction wells are needed. 1-B and 2-C extraction wells are needed. These wells are already installed.	\$120,000	\$616,000	\$970,400	\$736,000	\$1,090,400
	Contractors Operations (5% of construction)	\$6,000	\$31,000	\$49,000	\$37,000	\$55,000
	Construction Cost Subtotal	\$126,000	\$647,000	\$1,020,000	\$773,000	\$1,145,000
	Bid Contingency (10% of construction cost)	\$12,600	\$65,000	\$102,000	\$78,000	\$115,000
	Total Construction	\$138,600	\$712,000	\$1,122,000	\$851,000	\$1,260,000
	Permitting and Legal (2% of total construction)	\$2,772	\$15,000	\$22,000	\$18,000	\$26,000
	Services during construction (8.5% of total construction)	\$11,781	\$61,000	\$96,000	\$73,000	\$108,000
	Total Implementation Cost	\$153,153	\$788,000	\$1,241,000	\$942,000	\$1,395,000
	Engineering Design Cost (1.5% of total implementation)	\$22,973	\$119,000	\$187,000	\$142,000	\$210,000
	Total Capital Cost for MCL-Based Target Volumes	\$176,126	\$907,000	\$1,428,000	\$1,084,000	\$1,605,000
	Total Capital Cost for Background-Based Target Volume	\$176,126	\$933,468	\$1,626,230	\$1,109,593	\$1,802,356
	Percentage Decrease in Capital Cost if MCL-Based Target Volume is Used	0%	3%	12%	2%	11%
	Capture of Contamination that Exceeds Background					

target volume. Alternatives 3 and 4 would have capital costs that are 2 to 12 percent less than the background-based target volume counterparts.

6.5.4 Impact of Implementation Delays on the Cost of Alternatives

Any of the alternatives evaluated are scheduled to begin construction in 1995 (refer to the implementation schedules in Section 6.6). Delays in construction will increase the cost of remediation, primarily because the contamination in the groundwater will migrate further, creating larger target volumes that need to be remediated.

Groundwater modeling was performed to assess the impact of construction delays. Results from the modeling indicate that if a 3-year delay period occurred, the proposed groundwater extraction well locations for Alternatives 3 and 4 would still be adequate; however, the pumping rates would need to increase by approximately 50 percent (16 percent for each year of construction delay). This increase in flow implies an increase in O&M costs for the groundwater treatment system, as summarized in Table 6-15. Capital costs of the treatment system would also be impacted by a 3-year construction delay. Capital costs could increase significantly if construction delays extend beyond 3 years and the groundwater target volume increase is large enough to require new extraction wells.

6.6 Implementation Schedules for the Alternatives

Figures 6-12, 6-13, and 6-14 are estimates of implementation schedules for Alternatives 2, 3, and 4. The schedules for Alternatives 3 and 4 assume that Target Volume 2 (all aquifers) will be treated. The schedules include engineering design, development of bid documents, the attainment of all necessary permits, and installation.

Table 6-15 Impact of Construction Delays on the Cost of Alternatives						
Length of Construction Delay	Alternative 2	Alternative 3		Alternative 4		
		Target Volume 1	Target Volume 2	Target Volume 1	Target Volume 2	
1 Year	No Impact	\$40,000 capital \$41,000/year O&M	\$40,000 capital \$61,000/year O&M	\$40,000 capital \$41,000/year O&M	\$65,000 capital \$61,000/year O&M	
2 Years	No Impact	\$80,000 capital \$82,000/year O&M	\$130,000 capital \$122,000/year O&M	\$80,000 capital \$82,000/year O&M	\$130,000 capital \$122,000/year O&M	
3 Years	No Impact	\$120,000 capital \$125,000/year O&M	\$195,000 capital \$185,000/year O&M	\$120,000 capital \$125,000/year O&M	\$195,000 capital \$185,000/year O&M	

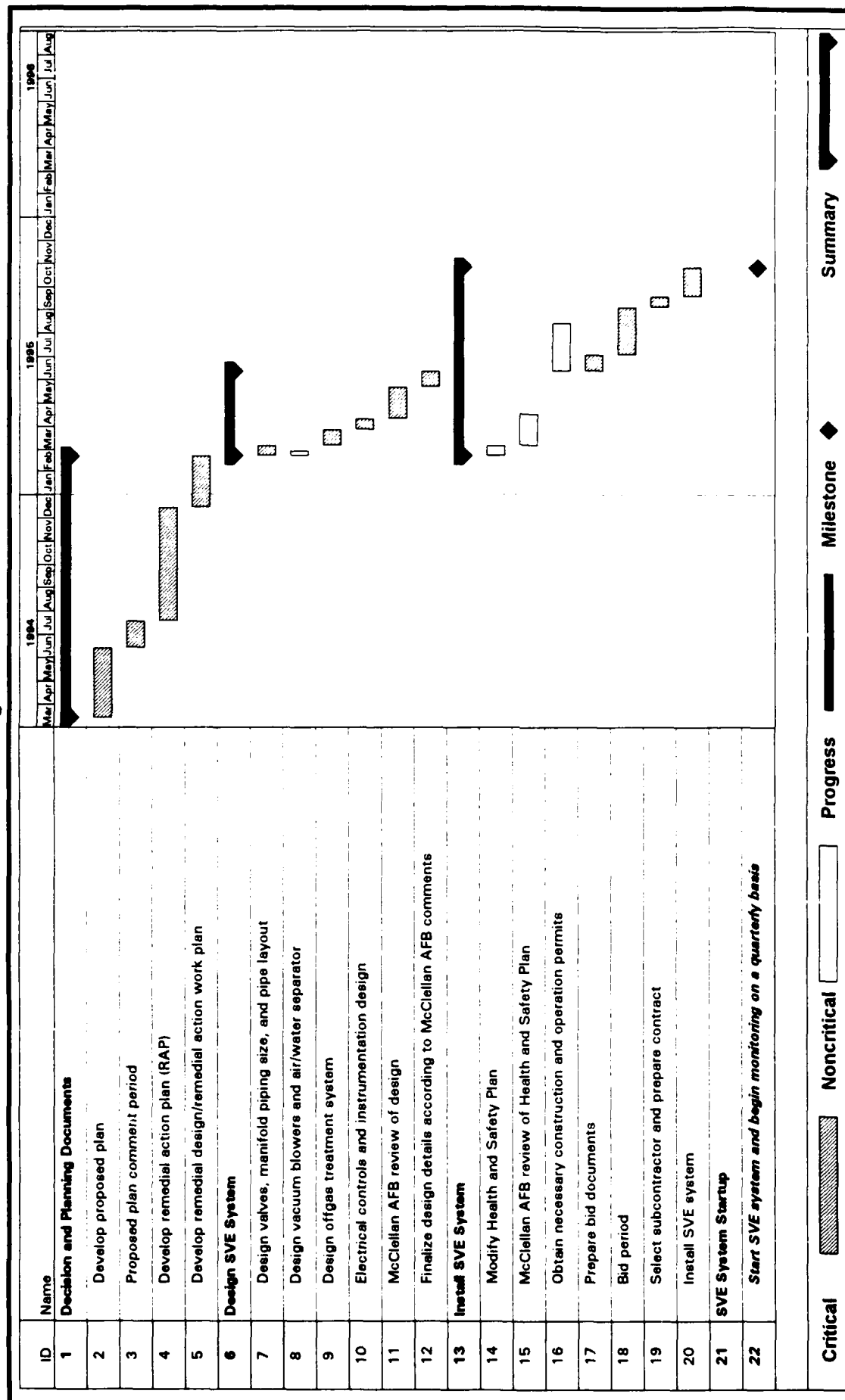


FIGURE 6-12
IMPLEMENTATION SCHEDULE
FOR ALTERNATIVE 2
 DAVIS GLOBAL COMMUNICATIONS SITE
 MCCLELLAN AIR FORCE BASE
 YOLO COUNTY, CALIFORNIA

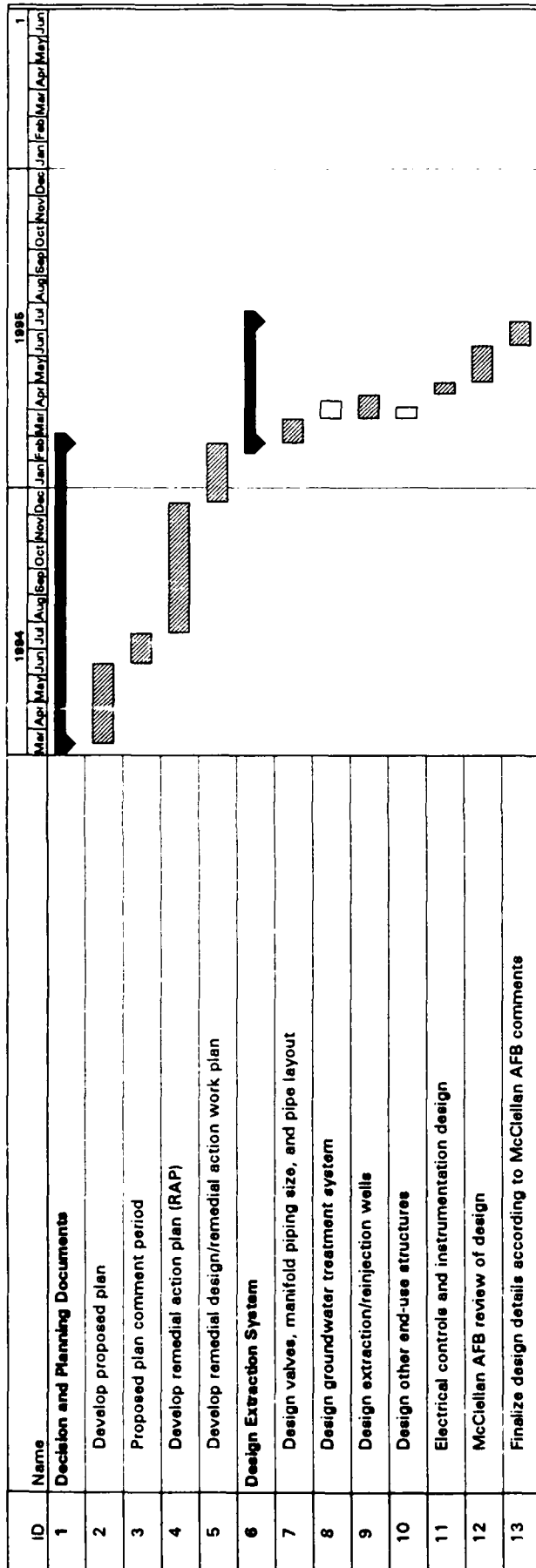


FIGURE 6-13 (page 1 of 2)
IMPLEMENTATION SCHEDULE
FOR ALTERNATIVE 3 (TARGET VOLUME 2)
 DAVIS GLOBAL COMMUNICATIONS SITE
 MCCLELLAN AIR FORCE BASE
 YOLO COUNTY, CALIFORNIA

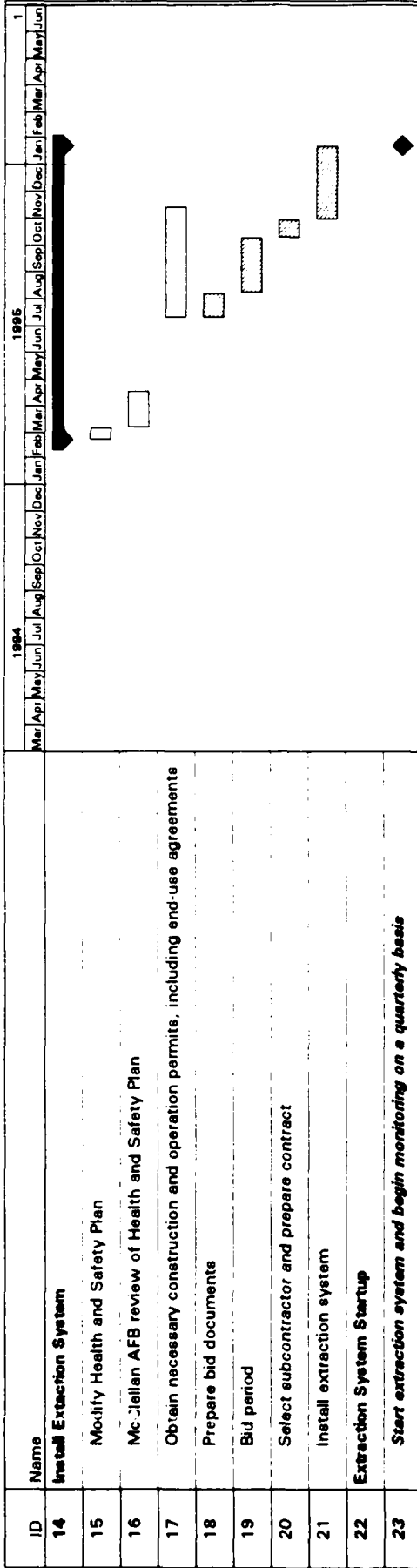
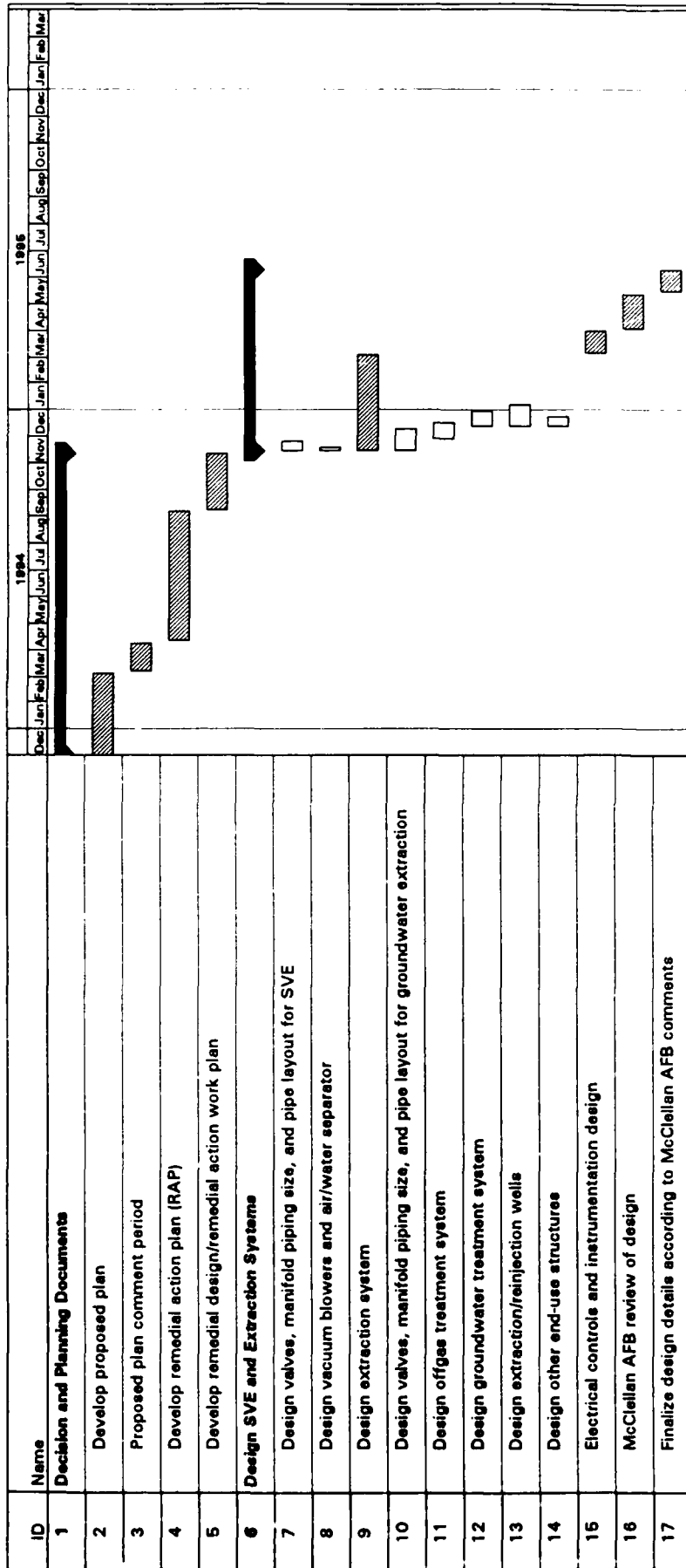


FIGURE 6-13 (page 2 of 2)
 IMPLEMENTATION SCHEDULE
 FOR ALTERNATIVE 3 (TARGET VOLUME 2)
 DAVIS GLOBAL COMMUNICATIONS SITE
 McCLELLAN AIR FORCE BASE
 YOLO COUNTY, CALIFORNIA



Critical

Noncritical

Progress

Milestone

Summary

FIGURE 6-14 (page 1 of 2)
 IMPLEMENTATION SCHEDULE
 FOR ALTERNATIVE 4 (TARGET VOLUME 2)
 DAVIS GLOBAL COMMUNICATIONS SITE
 MCCLELLAN AIR FORCE BASE
 YOLO COUNTY, CALIFORNIA

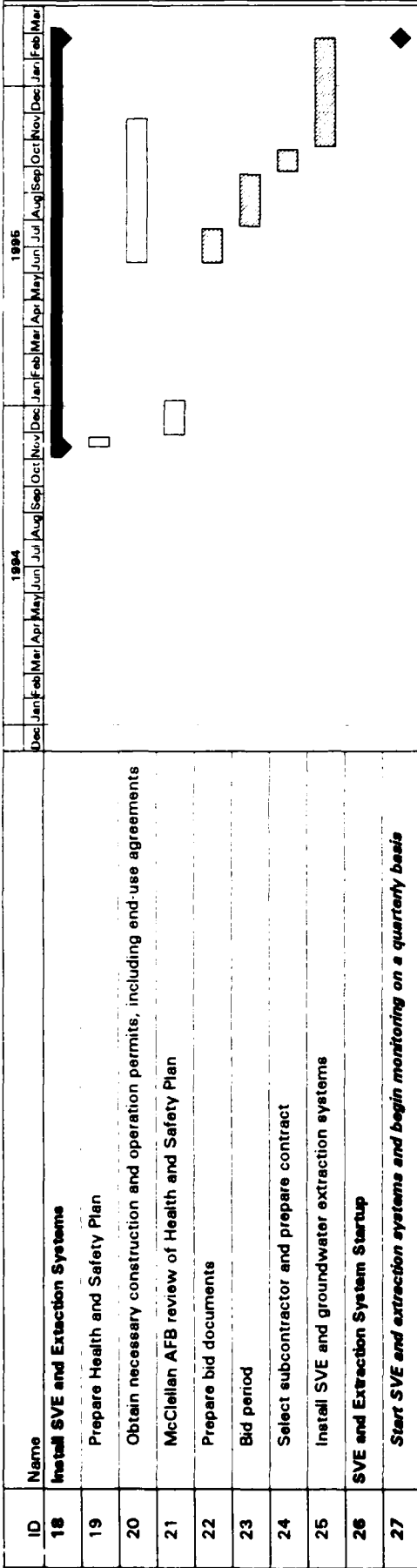
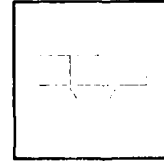
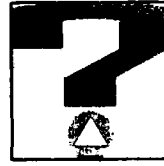
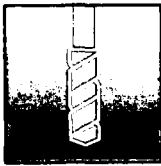


FIGURE 6-14 (page 2 of 2)
 IMPLEMENTATION SCHEDULE
 FOR ALTERNATIVE 4 (TARGET VOLUME 2)
 DAVIS GLOBAL COMMUNICATIONS SITE
 MCCLELLAN AIR FORCE BASE
 YOLO COUNTY, CALIFORNIA



Chapter 7 Conclusions

The following is a list of conclusions generated during the evaluation of this site. The conclusions are grouped according to chapter headings presented within the report.

7.1 Hydrogeologic Conditions

- Seasonal groundwater fluctuations cause the thickness of the vadose zone to double during summer months.
- The base of the B aquifer and the top of the C aquifer are indistinguishable beneath the site. Water levels, flow directions, and gradients from these two zones are approximately equal.
- Steep downward gradients exist beneath the site during the summer months causing downward flow from shallow, more contaminated aquifers to deeper, less contaminated, more transmissive aquifers.

7.2 Nature and Extent of Contamination

- Contamination residing in the seasonal vadose zone is mobilized by fluctuating groundwater levels aiding contaminant movement in all directions.
- Petroleum hydrocarbon contamination has been found concentrated at depths representative of the annual high and low groundwater levels.
- Tetrachloroethene (PCE) accounts for over 90 percent of the vadose zone contaminant mass and nearly 40 percent of the estimated groundwater contaminant mass.
- Over 88 percent of the estimated groundwater contaminant mass is made up of trichloroethene (TCE), PCE, and 1,1-dichloroethene (DCE). The total groundwater contaminant mass is estimated at 280 kg (617 lb).
- The estimated B aquifer dissolved contaminant mass decreased by half between May 1988 and February 1993.

- The contaminant mass present in the vadose zone will be a continuing source for groundwater contamination for several hundred years if left unchecked.
- VOC concentrations from groundwater samples from C and D aquifer wells south of the fenced compound have exhibited a trend of increasing concentrations since 1991. Therefore, VOC contamination is spreading downward and outward into the C and D aquifers.
- VOC samples from B aquifer monitoring wells, MW-1, MW-2, and MW-7, have shown an increasing trend in contaminant concentrations since February 1993.
- A continuous, coarse-grained C aquifer zone extending from beneath EW-1B to near MWD-10 is acting as a conduit for contaminant movement from a B aquifer source area near EW-1B to the C and D aquifers near Well Cluster MW3.
- Biotransformation in the form of anaerobic dehalogenation may be occurring in the vicinity of CH-5. This process may be a source of vinyl chloride in the B aquifer groundwater.

7.3 Problem Definition

- The results of the risk assessment do not indicate the presence of conditions posing imminent or substantial endangerment of human health or the environment.
- Remedial action is warranted at this site to satisfy the Regional Water Quality Control Board (RWQCB) nondegradation requirement for groundwater and vadose zone contamination. Groundwater and vadose zone contamination needs to be restored to background conditions.

7.4 Feasibility Study

- Soil vapor extraction (SVE) and treatment would likely reduce the vadose zone contaminant mass within 10 years to levels that do not threaten groundwater quality.
- The SVE and groundwater pump and treat alternative has the most likelihood of reducing or eliminating subsurface contaminant concentrations at the fastest rate. This alternative is the most costly.

7.5 Recommendations for Additional Work

Potential remedial actions for the COCs are listed in Table 7-1. Vadose zone and groundwater VOC contamination can be remediated through soil vapor extraction and treatment and groundwater extraction and treatment.

Table 7-2 contains a list of additional field investigations that are either planned to be performed at the Davis Global Communications Site or, if performed, would aid in the understanding of site subsurface conditions.

The field investigations have been categorized to distinguish when the action would take place and under which program activity the action would be conducted. Figure 7-1 shows the locations of recommended activities.

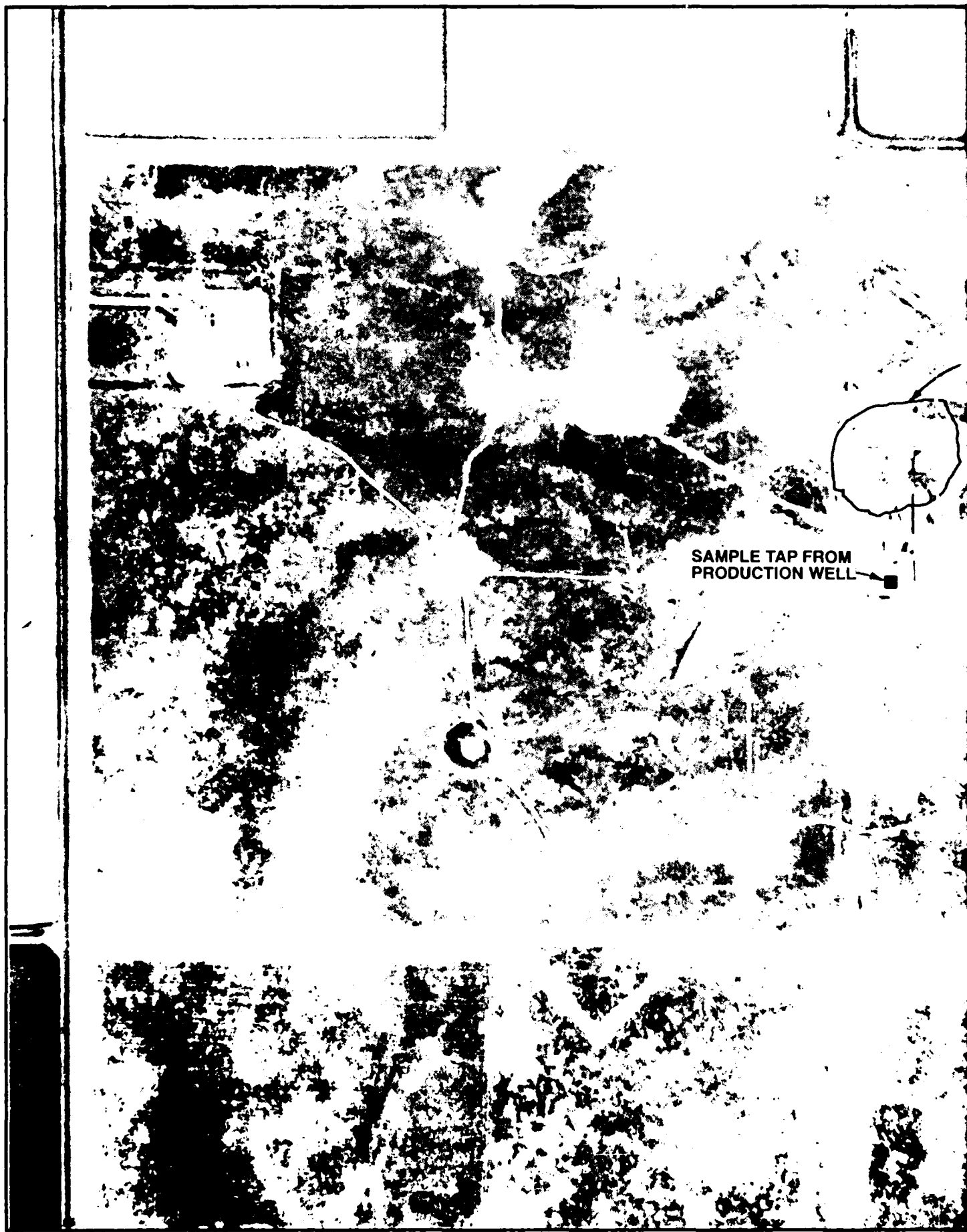
Table 7-1 Potential Remedial Actions for the Contaminants of Concern			
Compound	Contaminant of Concern in Vadose Zone ^a	Contaminant of Concern in Groundwater ^b	Potential Remedial Actions
Xylene		x	Groundwater extraction.
Benzene	x	x	Soil vapor, groundwater extraction, and soil bioventing.
Bis (2-ethylhexyl) phthalate	x		Soil bioventing.
Bromochloromethane		x	Detected in water from site production well. Trihalomethane (THM) chlorination production not present in groundwater. Verify presence.
Bromodichloromethane		x	Detected in water from site production well. THM chlorination production not present in groundwater. Verify presence.
Butylbenzophthalate	x		Soil bioventing.
Chlorodibromomethane		x	Detected in water from site production well. THM chlorination production not present in groundwater. Verify presence.
Chloroform		x	Detected in water from site production well. THM chlorination production not present in groundwater. Verify presence.
Dibenzofuran	x		Soil bioventing.
1,4-Dichlorobenzene		x	Groundwater extraction.
1,1-Dichloromethane	x	x	Groundwater and soil vapor extraction.
1,2-Dichloroethane	x	x	Groundwater and soil vapor extraction.
cis-1,2-dichloroethene		x	Groundwater extraction.
trans-1,2-dichloroethene		x	Groundwater extraction.
Di-n-butylphthalate	x		Soil bioventing.
Ethylbenzene	x		Soil bioventing.
Ethylene dibromide (EDB)		x	Ubiquitous agricultural contaminant not related to site activities.
Fluorene	x		Soil bioventing.
Methyl ethyl ketone		x	Detected in site production well. Groundwater extraction.
Methyl isobutyl ketone		x	Detected in site production well. Groundwater extraction.
2-methylnaphthalene	x		Soil bioventing.
Naphthalene	x		Soil bioventing.
o-xylene	x		SVE and soil bioventing.
Petroleum hydrocarbons	x		Soil bioventing.
Phenanthrene	x		Soil bioventing.
Pyrene	x		Soil bioventing.
Tetrachloroethene (PCE)	x	x	Groundwater and soil vapor extraction.
Toluene	x		SVE and soil bioventing.
1,1,1-Trichloroethane	x	x	Groundwater and soil vapor extraction.
1,1,2-Trichloro-1,2,2-trifluoroethane		x	Detected in site production well. Groundwater extraction.

Table 7-1 (Continued) Potential Remedial Actions for the Contaminants of Concern			
Compound	Contaminant of Concern in Vadose Zone ^a	Contaminant of Concern in Groundwater ^b	Potential Remedial Actions
Trichloroethylene (TCE)	x	x	Groundwater and soil vapor extraction
Trichloroethylene		x	Groundwater extraction
Vinyl chloride	x	x	Soil vapor and groundwater extraction
Non-halogenated	x		SVE and soil bioremediation

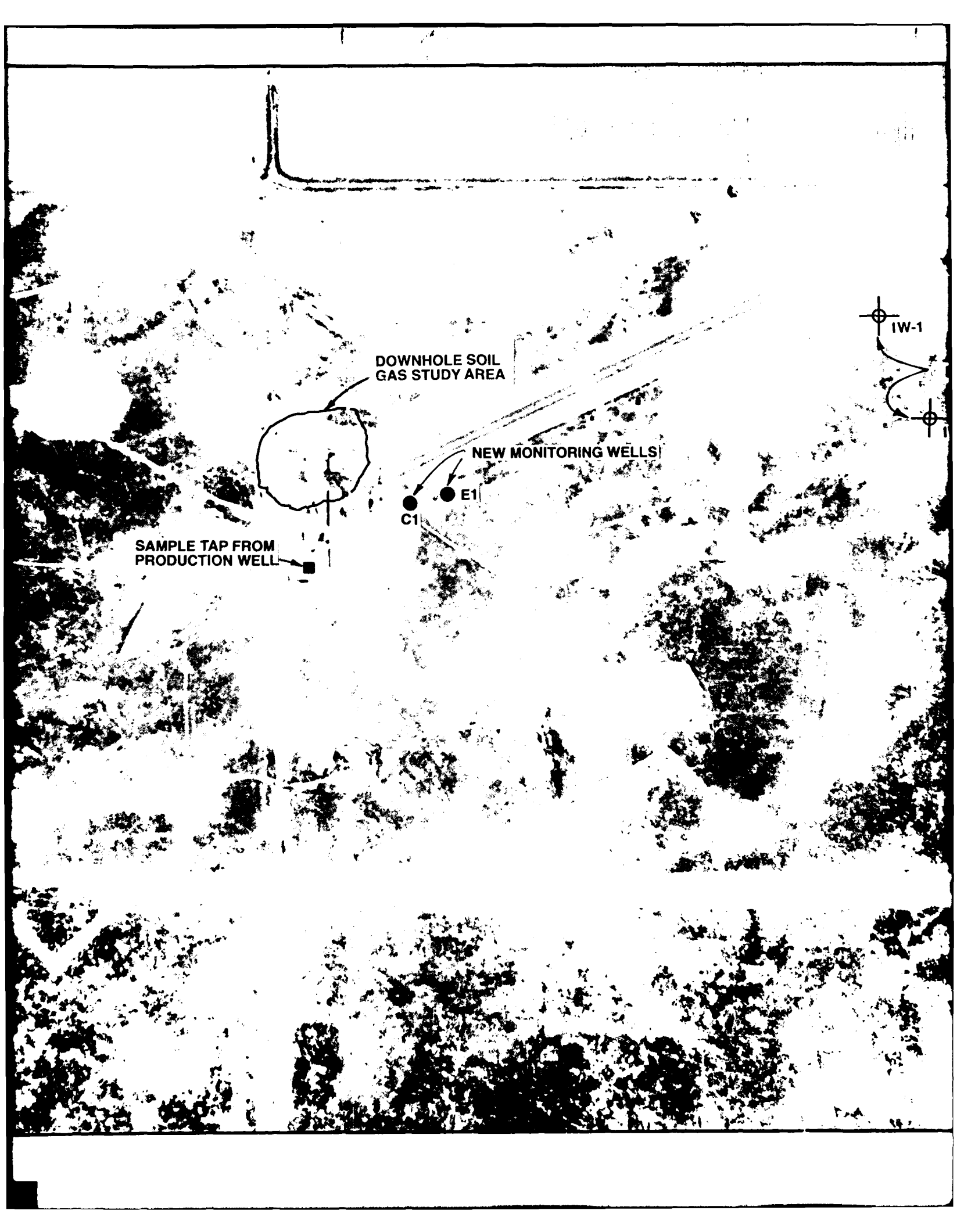
^aIdentified as a contaminant of concern for purposes of evaluating remedial action alternatives for vadose zone.
^bIdentified as a contaminant of concern for purposes of evaluating remedial action alternatives for groundwater.

Table 7-2 Recommended Additional Work	
Planned Investigations	Program Activity
Reinjection Well Drilling and Testing —Two reinjection wells are planned to be drilled south of the fenced compound area. One reinjection well is scheduled to be tested for injection components such as specific capacity during injection and clogging potential. Also an aquifer test will be performed to estimate the extraction potential of the well and to estimate aquifer hydraulic properties in the area of the well.	Next Phase Remedial Investigation
Horizontal Well Drilling and Pulsed UV Testing —A horizontal well will be installed within the B or C zones and tested for extraction potential. A groundwater treatability study will be performed using pulsed UV technology on contaminated groundwater from the site.	Innovative Technology
"Deep" Downhole Soil Gas Sampling —Ten boreholes will be drilled to a depth of 45 feet. Downhole soil gas samples will be collected from coarse-grained zones during drilling. The boreholes will be completed as soil vapor monitoring wells or piezometers.	Next Phase Remedial Investigation
Recommended Investigations	
Installation of Additional Monitoring Wells —One additional monitoring well in the E aquifer should be installed between EW-1E and EW-2E to monitor gradients during E aquifer extraction. An additional monitoring well should be installed in the vicinity of MW-4 to a depth of approximately 140 feet below ground surface (bgs). This well would function to monitor deep C aquifer contaminant movement. Additional D and E aquifer monitoring wells may be required for plume delineation if recent sampling results indicate contamination that is spreading in these aquifers.	Next Phase Remedial Investigation
Aquifer Testing of New Extraction Wells —Aquifer testing should be performed on the newly installed B and C aquifer extraction wells to estimate available long-term extraction rates and hydraulic properties in the vicinity of the extraction wells.	Interim Remedial Action

Table 7-2 (Continued) Recommended Additional Work	
Dual-Phase Extraction Testing —A dual phase pilot test should be conducted on Well FW-1B to determine the applicability of dual phase extraction at the site. Dual phase extraction may have the potential of expediting the vadose zone remediation process.	Interim Remedial Action
Recommended Investigations	Program Activity
Sampling for Biodegradation Products —There is some indication that anaerobic biodegradation is occurring in the subsurface in the vicinity of the former underground storage tank location. PCE and TCE appear to be converted to vinyl chloride in this area. Additional groundwater and soil gas sampling for ethene and ethane may show favorable results for biodegradation of PCE and TCE to ethene and ethane. Ethene and ethane are less hazardous byproducts of PCE and TCE degradation.	GSAP Quarterly Sampling; Bioventing Treatability
Sampling of the Site Production Well —Sample the site production well from locations both upstream and downstream from the point of chlorination. Trihalomethanes have been detected in water samples collected from the site production well. These contaminants are often the byproducts of the chlorination process. The samples from the site production well should be collected above the point of chlorination. However, the occurrence of trihalomethanes may be the result of a sample being collected downstream from the point of chlorination. A comparison of these two samples may provide an explanation for the occurrence of these contaminants.	McClellan A-8 Sampling Program



SAMPLE TAP FROM
PRODUCTION WELL



DOWNHOLE SOIL
GAS STUDY AREA

SAMPLE TAP FROM
PRODUCTION WELL

NEW MONITORING WELLS

C1

E1

IW-1

DIL
TEA

EW MONITORING WELLS

IW-1

REINJECTION WELLS

IW-2



0 400 800

SCALE IN FEET (Approximate)

DATE OF PHOTOGRAPHY:
JUNE 23, 1987

**FIGURE 7-1
RECOMMENDED FIELD
ACTIVITY LOCATIONS**

DAVIS GLOBAL COMMUNICATIONS SITE
MCLELLAN AIR FORCE BASE
YOLO COUNTY, CALIFORNIA

CRM HILL



Chapter 8 Works Cited

- CH2M HILL. 1992. *Data Summary Report for Aquifer Testing at the Davis Global Communications Site*
- CH2M HILL. 1993a. *Data Summary Report for January 1993 Aquifer Testing at the Davis Global Communications Site*
- CH2M HILL. 1993b. *Final Davis Global Communications Site Intermediate Remedial Design Report* June.
- Freeze, R.A. and J.A. Cherry. 1979. *Groundwater* Englewood Cliffs, NJ: Prentice-Hall, Inc.
- H & A. 1993. *Case Study-Xerox Building 209 2-Phase Vacuum Extraction System* Webster, New York.
- Hartley, Jim. CH2M HILL. 1993. Personal Communication to Alex Rafalovich.
- HydroGeoChem, Inc. 1989. *Revised Estimate of Volatile Organic Contaminant Mass at the Phoenix-Goodyear Airport Superfund Site* Goodyear, Arizona. July 19.
- International Technology Corporation. 1992. *Final Preliminary Remedial Investigation Report for the Davis Global Communications Site* McClellan Air Force Base, California.
- McClellan Air Force Base. 1991. *Installation Restoration Program Information Management System (IRPIMS) Data Loading Handbook*. Version 2.2 January.
- Jury, W. A., W. F. Spencer, and W. J. Farmer. 1983. "Behavior Assessment Model for Trace Origins in Soil: I. Model Description." *Journal of Environmental Quality* Vol. 12, No. 4.
- Radian Corporation. 1990. *Community Profile for the Davis Global Communications Site in Yolo County. Advanced Final for McClellan Air Force Base*. July.
- Radian Corporation. 1993. *Davis Site Letter Report October-December 1992* February.
- U.S. Environmental Protection Agency. 1988. *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*. Interim Final. EPA/540-89-004. OWSER Directive 9355.3-01.
- U.S. Geological Survey. 1960. *Geology, Water Resources and Usable Ground-Water Storage Capacity of Part of Solano County, California*. Geological Survey Water-Supply Paper 1464. Prepared in cooperation with the U.S. Bureau of Reclamation.
- U.S. Geological Survey. 1961. *Geologic Features and Ground-Water Storage Capacity of the Sacramento Valley California*. Geologic Survey Water-Supply Paper 1497. Prepared in cooperation with the California Department of Water Resources.